



OECD PROCEEDINGS

SUSTAINABLE MANAGEMENT OF WATER IN AGRICULTURE

Issues and Policies

The Athens Workshop

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*SUSTAINABLE MANAGEMENT
OF WATER
IN AGRICULTURE:
ISSUES AND POLICIES*

The Athens Workshop

PUBLISHER'S NOTE

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

FOREWORD

The Workshop on the Sustainable Management of Water in Agriculture, hosted by the Greek Ministry of Agriculture, was held in Athens on 3-6 November 1997, and included a one-day study visit to areas irrigated by groundwater affected by salt water intrusion. It was opened by the Greek Minister of Agriculture, and brought together around 70 participants from agriculture and environment ministries in 16 OECD Member countries, the Commission of the European Communities (CEC), one Observer country, 5 international organisations (CIHEAM, FAO, UN-DESA, UN/ECE, the World Bank), 3 international non-governmental environmental organisations (BirdLife International, IEEP/CLM, WWF) and one professional farmer organisation (CEA). Their participation was particularly useful in widening the area of discussion.

The OECD Secretariat presented an overview paper, and six consultant papers examined the nature and measurement of pressure on water quantity and quality from agriculture. A set of case studies, prepared by countries, described specific policies and practices addressing the issue of sustainable water management in agriculture.

The Workshop was an integral part of the programme of work on agri-environmental issues in the OECD. Its purpose was to define the key policy issues and the experience and role of different policy measures and market solutions in OECD countries, in the context of the sustainable management of resources and agricultural policy reform, and to suggest areas that might require further work to be undertaken in the OECD. An oral summary of the content and the discussions of the papers, introduced by the rapporteur led to a broad consensus on the conclusions that emerged from the Workshop.

The summary and the conclusions of the Workshop were submitted to the Joint Working Party of the Committee for Agriculture and the Environment Policy Committee under the written procedure. Subsequently, the Committee for Agriculture and the Environment Policy Committee agreed to recommend the derestriction of this document, which is published under the responsibility of the Secretary-General of the OECD. The conclusions of the Workshop, the overview paper from the OECD Secretariat, the Summary by the rapporteur, the conceptual papers prepared by consultants, papers by the FAO and the World Bank (invited speakers), official statements, and summaries of the case studies, are included in this publication.

Thirteen OECD Member countries, the CEC, CIHEAM and the UN/ECE, prepared case studies describing specific policies and experiences addressing the issue of sustainable water management in agriculture. The full set of case studies is available separately on INTERNET, as a general distribution document.

The OECD expresses its appreciation to the Greek authorities for the very active role they played in preparing, arranging and hosting the Seminar, as well as to the eight other financial contributors: Canada, Finland, France, Japan, Spain, Switzerland, the United States, and the Commission of the European Communities.

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CONCLUSIONS OF THE WORKSHOP

The sustainable management of water in agriculture is becoming a key issue for policy makers in OECD countries. In examining the concepts, issues and diverse country experiences in a multi-disciplinary context, the Workshop highlighted the policy linkages between agriculture, water and the environment. It generated a wealth of information, data and analysis on the various environmental effects linked to water quantity and quality in agriculture, and the allocation, pricing, institutions and property rights for water across competing demands. While there have been notable achievements in addressing the issues in the sustainable management of water in OECD countries, much remains to be done. The Workshop made an important contribution to the ongoing OECD work on agricultural policy reform and the environment, and the development of agri-environmental indicators, and opened the way to assessing the commitment of OECD countries to sustainable development.

1. Overview

Globally, demand for water for human needs has been growing at more than twice the rate of the population increase during this century, and already a number of regions are chronically short of water. Measured in terms of the availability of (renewable) water per capita, pressure on water resources is of concern to only a limited number of OECD countries. However, little attention is paid to water requirements for the environment, and even in countries with ample overall water resources, local or seasonal competition for water can arise in some areas, while drainage systems may be necessary in others.

Over the last decades, most of the increase in the world's food supply has come from the expansion of irrigated lands, which now account for around 20 per cent of the volume and about 40 per cent of the value of crop production on 17 per cent of agricultural land. The productivity of irrigated land is, globally, double that of rain-fed land. This expansion of irrigation — combined with increased use of high-yielding crop varieties, fertilisers and pesticides — has enabled growth in world food production to outpace demographic growth. It has also helped reduce the uncertainty associated with variable rainfall.

Over two-thirds of the water used in agriculture arrives directly as rainfall, while the remaining third is supplied to farmland either via surface diversions or is pumped from underground reservoirs. Globally, 70 per cent of the freshwater diverted for human purposes goes to agriculture. Agriculture's share of water use in the OECD area is around half of that, but in most countries and in many regions it is nonetheless the leading user. In some countries, there has been an excessive use or abstraction of water. Whether there will continue to be a sufficient *quantity* of water available in the future to meet not only the requirements of agriculture but also the needs of industries, households, and the environment is an emerging policy issue. Advances in irrigation technology, and the ability and willingness of agencies responsible for water supply and farmers to adopt water-conserving

practices, and recognising the economic and environmental dimensions of this scarce resource will therefore be crucial.

In areas with an adequate balance between rainfall and water requirements, which includes much of the OECD area, the concern has for the most part been with the *quality* of water. Agricultural land can play an important role in absorbing rainfall — thus helping to prevent flooding — and in recharging groundwater aquifers. But as water runs off from or percolates through farmland it picks up nutrients, pesticides and other elements that have been added to the soil. Whether and to what extent such pollution causes problems for the environment depends on a wide range of often site specific factors, some under the control of farmers, others (such as the weather) not.

The effect of agriculture on water quality is potentially greater in irrigated areas, since the intensification of production methods and the high rate of evapo-transpiration associated with irrigation practices tends to concentrate not only farm chemicals but also those elements that occur naturally in the source water itself. Yet it is also recognised that agricultural activities and water may interact in ways that, if ceased, would be detrimental to ecosystems and the natural resources on which both depend. Some OECD countries are concerned with both water quantity and quality issues.

Governments have often responded to perceived problems of water management in agriculture by spending money. The bulk of public money spent on agricultural water projects has gone to develop new public water conveyance projects, to encourage farmers to pump more water from the ground, or to drain land that otherwise would be too wet to support profitable agriculture. In many cases, governments have offered generous financing terms for water projects, subsidised electricity tariffs, and provided cross-subsidies from other users. Projects have often been undertaken on the assumption that farmers would continue to be able to grow crops or raise livestock at prices inflated by border protection or other price support policies.

Increasingly, public funds have also been used to encourage producers to adopt or maintain good farming practices, to help underwrite farmers' costs of mitigating pollution, or of enhancing environmental protection. Examples include paying farmers to lower input use through changing production practices or to restore wetlands so that they again become attractive to wildlife, or through removing dikes.

Developments at both the national and international levels have begun to change the context in which governments are approaching these issues. Over the last decade, since OECD Ministers agreed on long-term goals for agricultural policy reform, underpinned by the 1994 GATT Uruguay Round Agreement on Agriculture, there has been a gradual downward trend in the level of market price support in most OECD countries, although overall support to agriculture remains high. Many Member countries are committed to gradually reducing preferential user charges for water supply and subsidised provision of on-farm irrigation facilities as these fall into the category of trade-distorting support in the Uruguay Round Agreement on Agriculture. Moreover, all OECD Member countries endorsed Agenda 21 during the 1992 United Nations Conference on Sustainable Development in Rio, which includes principles for sustainable water management. Governments are also under growing domestic pressure to address the environmental impacts of agricultural policies.

2. Policy conclusions

OECD countries increasingly recognise the importance of ensuring the sustainable management of water in agriculture. Many countries are examining the respective role of policies and market solutions to address this key issue. Where water is a scarce resource, it is imperative that farmers respond to appropriate signals that encourage and not impede them in using water in the most economically and environmentally efficient ways. This is especially important because the world-wide demand for food will grow in the future and there will be even greater demands on water for agriculture and pressures on the environment.

Agricultural practices and policies, water management policies (the pricing of water and its allocation among competing uses: for agriculture, urban and industrial uses, and for the environment), environmental policies, the institutional and legal framework, technology, and the availability of information all have important effects on water resource management. However, there are differences among OECD countries in the relative importance of each of these effects, and in the policy measures implemented to fulfil them. These differences in turn spring from different agricultural, environmental and economic conditions, and different perceptions of the role of water management in agriculture. In some countries or regions, irrigation and drainage have long been virtually synonymous with farming, some of which have stressed the rehabilitation of old irrigation and drainage systems to improve water use and environmental protection. In others water quality is a key issue related to agricultural activities.

Sustainable water resource management can contribute to the goals of economic and environmental efficiency, and to broader social goals. However, in striving to achieve these goals trade-offs will often be unavoidable, which points to the need for a mix of policies. An important step towards achieving these goals is to make policies and programmes related to water management in agriculture more transparent, and to undertake regular monitoring and evaluation of policies, and cost-benefit assessments of projects. A more cost-effective use of limited budgetary resources, and an examination of ways in which water resources are managed, could help to improve resource use efficiency and generate positive effects on the environment.

The Workshop helped to illustrate not only what has been achieved, but also why water is too often not being managed sustainably in agriculture, and focused on operational ways to change this state of affairs, in particular through reviewing the experiences in Member countries. A wide range of disciplines, experiences and perspectives were brought together to enrich the discussions, and put forward a number of recommendations to policy makers on how they might better design and implement coherent policies in the areas of agriculture, water and the environment. While many countries have taken steps to reform policies that will improve the sustainable management of water in agriculture, more remains to be done.

3. Policy recommendations

A broad consensus emerged in the Workshop about the directions for policies aimed at achieving the sustainable management of water in agriculture in a long-term perspective:

- *Agricultural Policy Reform:* Continue to reform agricultural policies in ways that contribute to reduce distortions in agricultural production and the use of water resources,

improve the quality of water, and enhance environmental benefits associated with water use in agriculture.

- *Transparency*: Improve the transparency of water management policies in order to identify the full economic, environmental and social costs and benefits of water use in agriculture, and any associated transfers between farmers, taxpayers and consumers.
- *Cost-benefit analysis of projects*: Before considering major new or replacement investments in water projects, investigate possible other solutions to dealing with water issues; where investment and infrastructure for water projects are necessary, undertake cost-benefit analyses that consider economic, environmental, hydrological and social factors, and also take account of the effect on output and input prices of policies and policy reforms.
- *Indicators and information*: Improve the information available to policy makers, including clarifying the extent and nature of environmental impacts and developing appropriate indicators of the effect of agriculture on water quantity and water quality, covering driving forces, state of the environment and policy responses.
- *Agri-environmental linkages*: Improve the information on the agri-environmental processes involved in the linkages between agriculture, water and environment, such as by funding public and private research and development, and disseminating information and advice to farmers; build a better body of knowledge about the hydrological and environmental aspects of water systems, and the relationship between water resources and water quality and policies, for the decision-making process necessary to improve the sustainable management of water.
- *Water rights*: Clarify water rights systems, including mechanisms to deal with extreme events, and, where appropriate, encourage the development of markets and other arrangements to facilitate trade in water rights; strengthen the legal framework and institutions to promote greater efficiency in the allocation and use of water, and to meet clearly identified environmental needs.
- *Institutions and policy coherence*: Seek innovative approaches and appropriate institutional frameworks to integrate public, private and co-operative ways to manage water supplies, taking into account local and regional conditions; ensure greater consistency and integration in policy design and implementation, involving macroeconomic, agricultural, environmental, and water policies, including the implementation of international agreements and other arrangements that affect water and agriculture.
- *Water pricing*: Establish mechanisms to enable the introduction or strengthening of pricing, charging and allocation methods for users and beneficiaries of water (including farmers), including economic and environmental costs (*user pays and polluter pays principles*), and benefits (*beneficiary pays principle*), while taking into account social conditions.
- *Payments to farmers*: Where a payment is deemed necessary to help farmers adjust to higher prices for water resulting from the implementation of reforms, such as the

adoption of greater water cost recovery, or the adoption by farmers of water conserving methods, it should be in the form of income support not linked to commodity production or past crop yield, be transparent, and provided only as long as necessary to meet clearly stated objectives, including those conditional upon good agricultural and environmental practices.

- *Involvement of stakeholders*: Ensure that all stakeholders are involved in the design of policies, and the planning and management of water resources; seek ways to encourage farmers, water service providers and users to form associations aimed at improved water management; incorporate a multidisciplinary, integrated approach towards water policy.

4. Implications for OECD work

The Workshop identified further work that needs to be undertaken to help policy makers to design and implement relevant policies in an operational way, and to promote a more integrated approach toward agricultural, environmental and water policies. Such further work could include:

- Advancing the work on analysing the costs and benefits of policies, and developing indicators to help policy makers to better evaluate the effect of agriculture and agricultural policies on water quantity and water quality (see Annex).
- Examining and evaluating the institutional arrangements to achieve a coherent approach to water, agriculture and environment policies, including the systems of water rights.
- Identifying ways to promote the efficient allocation of water resources between agriculture and other users, including the environment, by defining in a policy-operational way the concept of full-cost recovery, taking into account the economic, environmental and social conditions, and by helping to improve cost-benefit methodologies.

ANNEX TO CONCLUSIONS

DEVELOPING INDICATORS OF AGRICULTURAL WATER USE AND WATER QUALITY

During the Workshop, Expert Groups discussed the development of indicators on agricultural water use and water quality, as part of a set of OECD agri-environmental indicators. Related indicators concern nutrient and pesticide use, soil quality, biodiversity and farm management (covering irrigation management) [see OECD (1997), *Environmental Indicators for Agriculture*]. The Experts recognised it was important to develop common methodologies which are applicable to all the Member countries and to take into account trends over time, and the regional or watershed dimension in building national series.

Agricultural water use: the Workshop suggested the initial development of five indicators at national level. The first three indicators measure the *pressure* from agriculture on water resources, although there is a need to develop a methodology to measure the volume of water use in the case where water is being re-used downstream, including by agricultural activities. The water stress indicator measures the *state* of water resources. The cost recovery indicator is a measure of *response* from policies which may lead farmers to use water more sustainably, although there is a need to develop a methodology to measure the environmental impacts of water use in agriculture.

- **Water use intensity:** the share of agricultural water withdrawal in total water withdrawals (industry, public water supply, etc.). Withdrawal is defined as water taken from surface and/or groundwater sources and conveyed to the place of use. To place this indicator in its overall environmental context, it should be supplemented by monitoring the total water withdrawals as a share of total renewable water resources (renewable water resources are defined as rainfall and transborder flows net of evapotranspiration).
- **Water use (technical) efficiency:** water use (litres) per unit (kg) of crop/livestock output. This indicator should take into account the technical water use efficiency of different irrigation systems (e.g. drip, sprinklers, etc.) and, as appropriate, various other factors, including climatic conditions, crop types, soil conditions, etc..
- **Water use (economic) efficiency:** water use (litres) per value of agricultural output (crops/livestock products). This indicator could also be disaggregated to look at the economic water use efficiency of irrigated versus rain-fed agriculture.
- **Water stress:** share of river length/groundwater reserves with average annual flow rates/water table levels, that are below reference minimal flow rates/recharge levels.
- **Cost recovery:** share of recovery of the full costs (government and private expenditures) for the provision of water supply to agriculture, including the establishment, operation and maintenance of irrigation and drainage infrastructure, taking into account any environmental impacts of water use in agriculture.

Agricultural water quality: The workshop suggested the initial development of four *risk* indicators, as well as collecting data on the *state* of water quality with respect to the contamination from agriculture. At present, collection of data on the state of water quality is difficult and costly, and distinguishing between agricultural and non-agricultural sources of water pollution is not easy at the national level. The Workshop also recommended that national water quality standards provide a reference for comparison with water quality indicators.

- ***Risk of nutrients in water:*** the risk of water contamination (surface and groundwater) from agricultural nutrient use (e.g. nitrogen, phosphorous), based on nutrient surplus, water supply and the capacity of soil to store water. This indicator will draw on OECD work that is underway on other indicators, particularly nutrient balances, water use, land use and conservation, and soil quality.
- ***Risk of pesticides in water:*** the risk of water contamination (surface and groundwater) from agricultural pesticide use, taking into account the degree of toxicity of pesticide active ingredients and their likely persistence and mobility in the environment and the methods of pesticide application. This indicator will draw on OECD work that is underway on pesticide risk indicators.
- ***Risk of soil sediment in water:*** the risk of soil sediment loading in surface water from the erosion of soil from agricultural land. This indicator will draw on OECD work on soil quality indicators.
- ***Aquatic biodiversity:*** the impact of agriculture on biodiversity related to surface water habitats, measured through the number and populations of key aquatic species which indicate changes in water quality due to agricultural activities, such as from nutrient and pesticide contamination. This indicator is closely related to OECD work on developing indicators related to agriculture and biodiversity, and wildlife habitats.

OVERVIEW OF THE MAIN ISSUES AND POLICIES

by Gérard Bonnis and Ronald Steenblik
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1. Introduction

Water is an essential input to agriculture. Governments — at various levels — play a crucial role, both in setting water policies and establishing property rights to the resource, and in providing infrastructure to convey water to users. Environmental policies, such as those establishing water quality standards, and agricultural policies, by influencing where, what and how farmers produce, also impact on the management of water in agriculture. Given the many points of intersection of these three policy areas — water, agricultural and environmental policies — changes in any one of these policies cannot be considered in isolation. Such a realisation is one of the forces behind the movement of OECD countries towards a more integrated approach to water management.

There is a considerable and growing interest in environmental issues related to water resource management within OECD Member countries. Most countries face at least seasonal or local water quantity problems, such as droughts, shrinking groundwater reserves and falling groundwater tables. In the more arid regions, resources have become at times so limited that demands for water cannot be met without exceeding sustainable rates of use in terms of quantity and possibly of quality. Agriculture is the leading consumer of water in many countries and is a major contributor to nitrate and phosphorous loading in surface, ground and marine waters, mainly the result of its use of chemical fertilisers and the concentration of livestock production.

In many countries tensions caused by competing claims over resources crossing or shared by subnational units have been major impediments to the efficient management of water. Most Member countries now recognise that the needs of the environment for sufficient supplies of water cannot be neglected. Policies affecting flows in rivers, or abstractions of groundwater reservoirs, especially those involving the diversion of water for irrigation (which often leads to higher concentrations of pollution downstream) have added to friction over water rights. With demands for water users — from all sectors — expected to continue to grow, the potential for disputes is likely to increase. Pressures on water resources often are not confined by national or subnational borders. In both North America and Europe, there are several international river systems that originate in one country and pass through or terminate in another.

Adding to the general concern over the sustainable use of water are the uncertainties surrounding the possible effects of global climate change. If temperatures were to rise significantly as a result of an

enhanced greenhouse effect, both rainfall patterns and evapo-transpiration rates would likely be affected. Work is still developing in this area, and it is still too early to say with confidence which regions would be most affected, and in what way, but some OECD Member countries could well experience an increase in rainfall, while others could witness a decline. Clearly, any such changes would have major implications for agriculture, water, and the environment.

The Workshop can provide an important opportunity to contribute to the policy dialogue within this broad policy context from an OECD perspective by:

- examining the nature and evaluation of the impact of agriculture on water use and water quality;
- sharing experiences of policy measures and approaches in the area of sustainable water management in agriculture;
- focusing on the numerous linkages between water management, agricultural and environmental policies, within the broader context of trends in the overall demand and supply of water;
- elaborating recommendations with a view to achieving a coherent approach to water, environment and agricultural policies, in the context of the reform of agricultural policies and the sustainable use of water resources.

2. The interface between agriculture, water and the environment

The share of agriculture in OECD's annual freshwater *withdrawal* is more than 30 per cent, and withdrawals for agricultural purposes currently account for 50 per cent or more of total water use in at least six OECD Member countries. Because of losses through evaporation and transpiration, agriculture's share of water *consumption* is typically much higher. In the United States, for instance, agriculture accounts for around 42 per cent of total withdrawals, but 84 per cent of consumption. Over the past 30 years there has been a continuous upward trend in the irrigated area for most countries, and the ratio of the irrigated to total cultivated area has also risen. Although only about 15 per cent of the OECD's cropland is currently irrigated, the share of the gross value of agricultural production contributed by this land is higher, probably at least 20 per cent. Clearly, agriculture has had a major impact on water use, and the supply of water has played a major role in boosting agricultural yields and output.

The expansion of surface-water fed irrigation in most OECD Member countries appears to be approaching physical, if not financial limits (with the notable exception of Turkey). But exploitation of ground water aquifers for various farming needs continues to grow. And whereas large-scale, surface-water fed irrigation is mainly characteristic of semi-arid regions (with the notable exceptions of Japan and Korea, where irrigated rice is grown under humid conditions), water abstractions fed from ground water are expanding throughout the majority of OECD Member countries. Increasingly, groundwater abstractions are beginning to exceed rates of replenishment. While agriculture is not the only sector which burdens the environment with emissions of pollutants, for most OECD countries it is a major contributor, accounting for around two-thirds of nitrogen emissions into surface and marine waters and about one-third for phosphates.

The long-run cost to the environment of using water in agriculture has often been high. Environmental issues associated with the use of water by agriculture include water quantity, soil quality, water quality, biodiversity and habitat, rural amenities and micro-climate. Pumping groundwater at unsustainable rates has contributed to the lowering of groundwater tables (and sometimes to land subsidence) and, in some coastal areas, to saltwater intrusion. Inappropriate irrigation practices, accompanied by inadequate drainage, have often damaged soils through over-saturation and salt build-up. The use of water by agriculture may result in soil erosion or water logging. Many water quality effects have also been created or aggravated by changes in stream flows associated with agriculture's consumptive uses. In general, reduced flow tends to concentrate pollutants such as pesticides and nutrients, and to raise the average temperature of rivers. Changes in flow rates and seasonal variations may lead to wetland loss and alter the biological cycles of aquatic and riparian plants and animals, including important commercial fisheries, like salmon. The diversion of watercourses for agricultural purposes may lead to the loss of rare and valued scenery, as well as of historical, cultural and archaeological sites.

Key water quality issues related to agricultural activities include eutrophication, contamination, turbidity, deoxygenation, acidification and salinisation. Environmental pollutants that may originate from agriculture are mainly nutrients, pesticides and soil sediment, but agricultural pollution of water from organic matter, acid substances, heavy metals, biological contaminants, and mineral salts can also be important in some regions and for certain countries.

3. Agricultural policy reform and water management

The driving force behind the development of water supplies to agriculture has been the concern to improve self-sufficiency or even to increase exports of irrigated agricultural products. However, the financial cost to taxpayers of providing water to farms, especially where it has involved developing surface water resources, has been great. Most of the costs of building headwork (dams, reservoirs, aqueducts), and much of the costs of installing local and farm-level infrastructure, have been underwritten by governments. Governments usually attempt to recuperate some of these costs through user charges, but typically revenues are enough to cover only operation and maintenance costs, and often not even these. Moreover, farmers generally have free access to ground water resources; in only a few places do governments (usually subnational authorities) charge farmers for water that they pump themselves; even in these jurisdictions it is doubtful that the fees collected fully reflect the opportunity costs to society of agriculture's consumptive use. Moreover, several countries continue to offer preferential tariffs for electricity used to pump water for irrigation.

Several reasons are often cited as to why full-cost pricing is uncommon in respect of irrigation water. One relates to the difficulty of attributing costs of multiple-purpose infrastructure to different uses, especially when one of the purposes is the generation of hydroelectricity. In some countries water is treated as a public good, and therefore so is the infrastructure built to collect and distribute it. Measurement of withdrawals is often based on crude instruments (or on the basis of capacity), rather than metered flows. Good information on the full extent of underpricing is, for these reasons, often difficult to obtain. What is generally acknowledged is that the numbers are large.

The economic and environmental distortions caused by the underpricing of water used in agriculture have led policy makers in a number of countries to take steps to reduce the public role in providing irrigation infrastructure; to eliminate, or at least to reduce, the implicit subsidies built into water prices; and to encourage the spread of advanced technologies to minimise water requirements and

reduce pollutants in discharge water. Even in countries where rainfall is normally abundant, increasing demand — particularly for clean groundwater — has demonstrated that water can no longer be treated as a free resource. In response, several countries have started to charge farmers for private withdrawals of groundwater, in order to ensure that supplies are adequate to meet the needs of other consumers, and of nature.

Agricultural support policies, particularly those that are linked to the production of particular commodities, draws in resources, including water, into the particular activity, thereby indirectly driving up the price of water to other users. Moreover, government-sponsored R&D is often heavily weighted towards problems specific to irrigated agriculture (as opposed to extensive/dry-land). As with other forms of support to agriculture, the distribution of support associated with water subsidies tends to be skewed towards larger, irrigated units. Evidence from various countries suggests that benefits from irrigation subsidies typically accrue disproportionately to large farms. Where environmental damage has occurred, governments have in many cases paid farmers to adopt water-conserving practices or to clean up their discharges of irrigation or drainage water, raising questions of consistency not only with the User Pays Principle, but with the Polluter-Pays Principle (PPP) as well.

The effects on water resources resulting from the agricultural policy reform process will depend on the extent to which incentives facing farmers change. The overall level and means of support afforded by farmers vary considerably across countries. Increased exposure of producers to world market prices (which may not reflect the full environmental costs and benefits of agricultural production) may not lead to more sustainable use of water and lower discharges of environmental pollutants by agriculture. The reallocation of water resources to other consumptive uses within and outside agriculture as a result of support reduction will benefit the environment to the extent that environmental impacts are accounted for in farmers' decisions. In some cases, specific environmental policy measures would be needed in addition to agricultural and water policy reform.

4. Key policy issues associated with the sustainable management of water in agriculture

As countries proceed down the paths of agricultural and water-policy reform, they are having to grapple with a wide range of issues, some specific to their local circumstances, but many that are common to all. The suggested questions outlined below are to help focus the Workshop and identify the key policy issues associated with the sustainable management of water in agriculture.

- *What is the extent of government involvement in the supply and management of freshwater resources used in agriculture and in preventing and controlling water pollution originating from agriculture? How do existing laws and institutional frameworks — in particular, systems of property rights — influence the nature and scope of government policies affecting water use and pollution by agriculture? How much of the cost of developing water supplies for agriculture is ultimately borne by taxpayers or by other users? What are the opportunity costs to other current and future consumers of unregulated and under-priced abstractions of groundwater for irrigation and livestock watering?*
- *What are the linkages between agricultural policies and water management policies and practices? To what extent is policy making in each sphere (water supply, agriculture, environment) influenced by policy making in the others? In general, to what extent are*

reforms of agricultural policy and of water policy complementary? Which commodities would be most affected by water policy reforms?

- *What have been the effects of water policies on agricultural production and the environment?* How do water management and other relevant policies influence crop mix, yields, farm structure, and production and trade? How have these policies affected agricultural practices and hence the environment (such as soil structure and water quality)? What indicators are best suited for measuring the impact of agriculture on water use and water quality?
- *What potential conflicts are likely to arise between agriculture and other competing uses?* What are the needs for water from an environmental perspective? Should agriculture receive priority over other uses? What criteria (where complete markets do not operate) should be used to arbitrate conflicting claims?
- *What is the scope for applying water-conserving and water pollution prevention technologies and practices?* How do changing water and commodity prices affect the rate of adoption of these technologies and practices? Is there a greater role for government policies to promote R&D, training and advice in this area?
- *In what direction(s) should policies move in order to strengthen the ability of agriculture to use water in a sustainable manner and to prevent agricultural water pollution?* What are the key elements of such responses? What lessons can be learned from countries' experiences in reforming water policies and related institutions, including changes in property rights over water? What kinds of complementary policy changes — such as to help farming communities adjust to higher water prices — might be needed?

SUMMARY OF THE WORKSHOP

by Otto Doering III
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Many critical issues were raised and discussed during the course of the Workshop in addition to the information presented in the consultant's papers and country studies. The focus of this summary are the themes of the presentations and the general direction of the discussion at the Workshop. For the specific concerns not covered here, there is a wealth of information in the consultant's reports and the country studies.

1. Understanding the problem

Water is a fundamental resource required for agriculture. Historians and geographers have recognised the critical role of water systems that sustained agriculture for thousands of years and were the basis for the growth of great civilisations in the Nile, Indus, and other great river valleys. In our century, the extension and addition of more irrigation has been critically important to the growth of world food supplies which, after the Second World War, increased at a faster rate than the growth of population. Over the last thirty years, world food availability has increased by 17 per cent while availability in the developing countries has increased by 27 per cent. Expanded irrigation has also been an important factor in the reduction of rural poverty. However, this resource is not inexhaustible. There is a limit to the availability of the water encompassed in the hydrological cycle and the accumulated ground water.

It is increasingly apparent that we have a problem with the availability of water. The **World Bank** gave a comprehensive outline of this with declining regional per-capita availability as one important measure. 70 per cent of the total world water withdrawal is used for agriculture, and half of that is lost to seepage and evaporation. Just the pressure of world population growth and the desired achievement of increased living standards means that agriculture is increasingly competing with other sectors for water while using more itself.

We are not just concerned with a quantity risk to sustainability. The high proportion of water used by agriculture, in and of itself, brings about some degradation of overall water quality and some modification of the environment. As this becomes better understood, people are beginning to recognise environmental degradation as dangerous to the prospects for human sustainability. There was a consensus in the discussion at the Workshop that the danger is real. People are beginning to view the health of the environment itself as an important signal of human sustainability, like the canary in the mine was the signal to the coal miner of imminent danger in the mine.

Another important observation that was confirmed by the Workshop participants is the great variation in the character and extent of water use and the ensuing problems in different places. One example is the presentation by **CIHEAM** which drew the important contrasts between the Northern and Southern Mediterranean countries in terms of water availability. These can be compared with the case of the **Netherlands** for an even greater contrast. Just the climatic and hydrological differences between places requires different approaches in order for there to be some prospect for success in a particular place.

The comparisons drawn in the consultant's studies and the contrasts between the country studies also demonstrate that no one political system or set of institutions guarantees success in solving water management problems. While local involvement by farmers and other stakeholders was stressed as being an important component of water management, this certainly is not a sole criterion for success. The discussion at the Workshop reflected increasing appreciation for mixed or combined approaches recognising important contributions to management from different stakeholders and levels of government. While the **French** approach presented by the regional water agency directly involves farmers as individuals and as associations of farmers on a community basis, their area of responsibility and authority is clearly proscribed at the level of the river basin by the river basin authority itself for broader water allocation concerns. In another case where the critical problem has been identified at the farm level, **Germany** is concerned with getting the right participation from farmers.

2. The situation we face

A major issue that we face is the increasing marginal cost of surface water supply delivery. Increasing marginal cost is the response to the growing desire from all sectors to use more of it. We also face a situation of universally declining water quality. The limitations on quantity and the problems of quality place further stress on the environment. Within agriculture we face increasing problems of soil degradation as part of the overall water and cropping system management.

There is a need for better understanding the situation that we face. A number of useful indicators were presented by *Jean Luc Redaud* that help us begin to gauge the impact of agriculture on water use. The Workshop participants accepted the fact that we are placing great pressure upon water resources, whether we look at water balances, per-capita consumption, the expansion of area under irrigation, exploitation indices, freshwater abstractions or nutrient pollution. One of the concerns is that this information is not as precise as we believe is necessary. We need to have better information for decision making and for management, and this is one place where international co-operation involving sharing of data and methodology has the prospect of making important contributions to better management of water resources. However, even without the precision desired for problem solving we agree that we do have a problem. The dilemma is somewhat like defining happiness. We may well know when we are happy but be unable to define it or its causes with precision.

In addition, there was a consensus that water for agriculture is generally underpriced. Water pricing has been socially and politically determined to favour the food producing sector, and this has led in many cases to extensive low value production from an increasingly valuable resource. One excellent example from the papers is the extensive growing of alfalfa in the **western United States**. As *Jean Luc Redaud* points out, underpricing leads to revenue shortfalls resulting in poor maintenance,

substantial water losses, and delays in new projects. Economical use of water is discouraged by underpricing or by flat rate water charges.

The pricing issue was discussed often in the Workshop. One observation is that very low water prices for agriculture can be providing benefits or making a contribution beyond the primary goal of low cost production. Both **France** and **Japan** stressed the importance of this. Such underpricing of the water resources may be extremely important in: reducing yield variability risk; helping achieve food self sufficiency; keeping people in farming; adding value to rural communities; and providing environmental services or landscape amenities. These are of special concern for **France**, **Japan**, **Greece** and several other countries at the conference.

One economic concern with this approach is that the indirect provision of a secondary benefit may be more costly than just providing that benefit directly, although this is not always the case as for the recharging of ground water with irrigation water in paddy fields. There may be inefficiencies in the indirect transfer, such as often exists with commodity price support programmes designed to raise farmer incomes. The primary problem with this indirect approach is that it may result, in some cases, in inefficient water use due to the underpricing of the resource.

The approach also has public policy impacts. It is not clear to the public exactly what they are paying for. Agricultural interests in many industrial countries have favoured an indirect approach to achieving income transfers to agriculture believing this to be more politically acceptable and easier to obtain. However, such an approach can be vulnerable when public expenditure needs to be reduced and specific accountability and performance are demanded for public expenditure.

Another important aspect of the situation we face is the impact of agriculture on water quality. *David Zilberman*, **Germany**, The **Economic Commission for Europe**, and other participants, pointed out that agricultural and other uses of water have greatly changed the condition or state of nature that existed previously. This has been caused by: water diversion and restoration projects; water logging and drainage problems; direct contamination from crop and livestock activities; and government agricultural policies.

In addition, *Alexandros Poulouvassilis* illustrated and described an example of the problem of salt water intrusion in **Greece**, yet another way that agriculture has changed the natural condition through groundwater withdrawal. A number of suggestions were discussed that dealt with the negative impacts of agriculture on water quality. These included economic incentives, regulatory approaches, technical applications, research, and technology transfer.

Brook Harker's presentation addresses the problem of being precise about the water quality problem that we face in agriculture. This problem is not unique to agriculture, and is reflective of the general difficulty we face assessing the change we actually cause by our presence and activities in natural systems. The measurement difficulties that we face in natural systems such as traceability of contaminants, time lags from the moment of contamination, and climate changes affecting transport and contamination, are only compounded by the practical considerations of monitoring costs and the number and dispersion of agricultural units with which we have to be concerned.

The importance of this is that the difficulty of assessing the extent (and cost) of environmental damage from agriculture makes it difficult to determine the level of abatement (and appropriate expenditure) necessary. From a technical and economic efficiency standpoint, it is often optimal to counter environmental degradation with an equivalent level of prevention or amelioration. The

message here is similar to the one concerning the difficulty of estimating adequately the degree of water quantity problems. The extent of appropriate action needs to be determined by the extent of the problem. The nature of the appropriate action is also determined by the nature of the problem. Here again, there is potentially high payoff to co-operative efforts that improve our information and ability to do a better job defining the nature and extent of the problem.

While the discussion of water quality focused on irrigation, *Jean Luc Redaud, Brook Harker*, the **FAO** and others, pointed out the importance of agriculture's impact on water quality in regions of rain-fed agriculture as well. Rain-fed and irrigation hydrology are often linked, so one may well affect the other. Other water users are equally concerned with water quality problems related to agriculture whether they come from irrigation or from rain-fed fields. **Switzerland** presents a particular case of water quality concerns from rain fed agriculture in a confined geographical space. Nitrogen and phosphorous pollution, much of it from animal agriculture, are receiving increased attention with several policies designed to achieve a balance between nutrient emissions and utilisation in order to reduce the impact of these nutrients on water quality to a minimum.

3. Adopting a forward looking approach

Often, public policy is reacting to past events. Much policy is marginal, making small adjustments to our current course of action. These marginal adjustments are often responses to past problems fresh in our minds. This certainly has been true of both water policy and agricultural policy. We see this very natural reactive problem solving in a number of case studies. Such an approach is conservative and useful. The question is whether it is sufficient for the problems that we face.

The water problems discussed in the Workshop are of increasing severity as we approach very real resource constraints. While we have dealt successfully with many water resource problems in the past, we did so under considerably less stringent economic conditions. The Workshop participants agree that we are facing problems of considerably greater difficulty than we have in the past.

The Workshop participants also agreed on the importance of being able to make the case for the policies and resources necessary for what needs to be done to successfully deal with anticipated future water problems. This case will have to be made to both politicians and to the public. It is difficult enough to make the case for today's more modest problems. Will it be possible to make the case for dealing with future problems of increasing magnitude? In order to do this, an important first step will be co-operating to create analytical systems and assemble information we now lack on the nature of our water quantity and quality problems and the consequences of different alternative ways to deal with them. Internationally agreed upon measures that are robust will carry more weight in the public debate.

4. Attacking the problem: some important concerns

The Workshop stressed the need to take into account local conditions, institutions, and social characteristics. These are extremely important to success in achieving sustainable use of water in agriculture. In many cases, what will be needed is a change from the current practices that are firmly entrenched in the particular social and political environment. As we approach such cases it will be critical to know well why people (or institutions) are doing what they are doing today. It is only with such knowledge that one will be able to compare a future course of action with today's, argue effectively for change, and then shape that change so that it will be acceptable. We will be forced to

acquire the knowledge of and respect for existing institutions and activities that will allow change to occur. French, American, and Meiji Restoration revolutionaries in Japan, understood the context in which their revolution was taking place and effectively utilised existing institutions to bring revolutionary change about. Successful achievement of sustainable use of water in agriculture may be equally revolutionary.

A second concern is the primary importance of the environment if sustainability of water resources is to be achieved. The Workshop discussion, the consultants papers, and the country case studies explicitly recognised the need to halt environmental deterioration and restore natural flows, biodiversity and other damaged environmental components to some degree. While there was disagreement about the degree of remediation necessary, this concern for the environment is an explicit criterion today for water resource management. It will have to include consideration for irreversible impacts and a more complete accounting for environmental benefits.

A third concern is equity or fairness in the distribution of resources to individuals or groups. Some participants in the Workshop were concerned that equity considerations have led to wasteful use of resources while another part of the group is concerned that efficiency of resource use may not be consistent with our sense of equity. The challenge will be to meet both objectives.

Finally, achieving sustainable water use in agriculture will involve many different kinds of decisions. The focus of the Workshop was primarily on those questions that can be scientifically and technically verified: efficiency of water use, the hydrologic requirements for sustainability, the role of incentives in encouraging farmers to use less water; which are all questions with a basis in fact. On the other hand, there are also critical questions such as considerations of equity that involve value judgements made by the public and their political representatives. If water use in agriculture is to be sustainable, the factual case will have to be made for those questions that can be addressed analytically. Economics, for example, is improving its capacity to analytically describe preferences of individuals in areas that were formerly speculative. But neither economics, engineering nor the other agronomic sciences will be able to give all the relevant answers to the questions posed by policy makers. The question is: which of the critical decisions will be analytically based and which will be based upon value judgements and perceptions? The participants in the Workshop stressed the need to expand the share of the critical decisions that are made on the basis of analytical science and well informed perceptions.

5. Where do we go from here?

An essential first step will be to bring transparency to the water allocation and management process. Transparency of costs, transfer payments, indirect benefits, water rights structures, and whatever else relates to water management and allocation is necessary. Only if there is transparency that allows clear observation of the full set of payments, transfers, benefits, and resource allocations can there be an estimation and analysis of the full consequences of the alternatives that are being suggested. Both *Jan Greig's* paper and several of the case studies illustrated the necessity of this. Transparency shines a searchlight on both benefits and costs. *Jan Greig* pointed out how critically important this is for farmers and other users because transparency means that users know exactly what they are paying for, so they can be sure they are only paying for services that actually benefit them. Transparency brings meaning to most alternatives being discussed — full cost pricing, marginal pricing, and so on.

A number of participants pointed to important indirect benefits to farmers from low priced water. With transparency, one sees whether the low cost of water results in its inefficient allocation, whether the actual benefits to farmers exist in fact and actually reflect the costs paid by non-farmers, and whether inefficient water allocation imposes a greater cost on other users and society than the benefits to farmers.

The need to take steps toward greater transparency in the management of water resources may be reinforced in cases where an overall process of reform in government policy towards agriculture is ongoing, as in the case of **New Zealand**, or in areas confronted with severe shortages of water, as in certain parts of **Australia**. In the Australian case, transparency also involves a comprehensive allocation system, including the needs of the environment, and covering all consumptive and non-consumptive uses. While this has high information requirements, it is essential in safeguarding the environment and other areas of concern that would not be able to compete in free market allocation because environmental, social and other beneficial uses are often undervalued in market terms. Dealing with this undervaluation of important aspects of water use while placing water in a more transparent market oriented allocation system is a major concern of the Workshop participants.

Water use and water quality in agriculture must be part of a larger water resource policy framework that includes many stakeholders. We see this throughout the papers, discussion, and the case studies in the Workshop. This is key to the issue of transparency and the recognition of scarcity. **Spain** in particular, illustrated the institutional complexity of the decision making process that may be required. In the case of **Spain**, water resource allocations are determined with participation from many levels of government, including the judiciary, as well as from a broad spectrum of users. This includes not just irrigators, but also representatives of town councils and industries. In **Canada**, both the Provincial and the Federal Government are involved which requires initiatives like the Canada-Saskatchewan Partnership Agreement on Water Based Economic Development.

There must be adequate knowledge of the hydrologic system we are dealing with. As shown in the case studies, contrasts in basic rainfall patterns and hydrology between the **United Kingdom** and **Spain**, between **Italy** and the **Netherlands** illustrate the basic differences in the water resource characteristics that will bring failure to a 'one approach fits all' management system. There is even greater contrast between these countries and the situation in **northern Canada** and **Finland** where freezing conditions exert a major influence on water availability and quality.

There must be recognition of scarcity and the treatment of water as an economic good. The Workshop recognised cases where water is not generally scarce, as in **Japan** and the **Netherlands**. However, there may be value in beginning to place water in an economic framework to better resolve problems of occasional scarcity (as evidenced by the recent droughts in California), and to establish a useful decision-making framework as water becomes scarcer through actual quantity restrictions or effective reductions through quality deterioration.

In considering water as a scarce resource, there were many options for policy actions suggested by the Workshop. These include: full cost pricing; marginal cost pricing; clear specification of water rights; the opportunity to trade water at certain times; full economic accounting for the needs of sustainability; a regulatory framework that meets user and environmental needs when the market fails; promoting the role of water users' associations for allocating and managing irrigation water.

In considering these options, the information in the table of market solutions and secondary effects in *Alberto Garrido's* paper (Table 1) is extremely useful. It illustrates the important trade-offs that have to be weighed when such decisions are being made. Further examples were given in the papers and case studies and the use of regulation in **Germany**, where markets may not be appropriate, provides an interesting case.

Different views exist about the extent to which water is treated as an economic good. *Alexandros Poulouvassilis* saw a danger where those with wealth are able to appropriate and possibly monopolise water that he believes is a public good essential for all humans and the environment. *Jan Greig*, on the other hand, does not see why the public should ensure water for those who do not manage it well enough to be able to pay its full value and still make a good livelihood. This contrast of views goes to the heart of one of the critical issues of the Workshop — the balance between public and privately driven (market) determination of water prices and thus water use. Very few people argued the extreme of complete public agency determination (where water may be underpriced and used inefficiently), and very few argue that the private market should allocate all water (where sustainability and the environment may have been insufficiently accounted for in the market). The common ground for this discussion at the Workshop was the general understanding that:

- in the past, public decisions have dominated and probably led to inefficient water use; and
- in order to meet the challenge of increasing water scarcity we may have to encourage a more market approach to water allocation to increase efficiency of its use and also encourage higher value use.

By way of an example, a past practice like using highly subsidised water in California to grow low cost alfalfa hay for dairy cows producing surplus milk (due to commodity support programmes) has to be questioned in the face of today's water realities.

There must be a high priority on substituting “knowledge” for “resources”. We will have increasing incentives to substitute as water becomes more scarce. What we need to do here was described by *David Zilberman* in terms of “management instead of concrete”. In other words, the greater application of knowledge and less reliance on water infrastructure can ensure the better use of scarce water resources. Substituting “knowledge for water” requires interdisciplinary co-operation and emphasises the importance of: basic knowledge and data; comparable quantity and quality indicators; institutional and social knowledge, planning and management skills; new technology and knowledge transfer.

There was also a recognition that some of this knowledge can be transferred from one region or country to another so that every place does not have to reinvent the wheel completely. Cross country or cross regional dialogues and transfers may have high pay-off.

There is a concern with transboundary issues. The **Economic Commission for Europe** emphasises the importance of this both with respect to water use and water quality. Many major water resources cross national boundaries and joint responsibility and action is required, as in the case of successful co-operation in reducing the pollution in the Rhine.

6. What needs to be done?

The Workshop highlighted some *key areas for action*:

There is a need to co-operate and improve the basic knowledge about water availability, use, quality and impact. This includes designing *appropriate indicators* for quantity, quality, and impacts (such as environmental stress). As part of the concern about water use there must be more stress on cropping system management. The recent decision in the **United States** to eliminate much of the agricultural meteorology system in the Midwest is an example of an important step in the wrong direction.

There is a special need in the knowledge area for ground specific *information on management and cropping system* alternatives. This is particularly highlighted here because pilot projects and other methods of gathering such information are under-utilised relative to their value in successful ground level adaptation, and in planning that recognises actual conditions on the ground.

There is a need for some degree of *comprehensive approach or coherence*, but efforts must be made to judge where this is and is not appropriate. Arbitrary application of principles or methods across political boundaries are unlikely to be useful. However, grouping political entities by similarity of characteristics and concerns and developing a closer linkage of information and experience sharing within similar groups makes good sense.

There is a need to meet the challenge of reclaiming those areas where *irrigation and water management investments* have been made and proved faulty or been abandoned. Such reclamation should pass strict economic tests and be compared with other alternatives, but there may be important opportunities here.

There must be creativity in spending the US\$600 to US\$800 billion forecast for *infrastructure* world-wide to ensure agriculture's water needs over the coming decades. One critical question will be what proportions of this we spend on "knowledge" and on "concrete".

7. Thinking about the future

Marginal change may not be adequate. If we believe in increasing scarcity more change will be required than in the past. If we add global climate change scenarios of increasing climatic variability, this has important consequences for agricultural water supplies. Recent work in Egypt assessing increased climatic variability has projected the need for multiplying the catchment capacity on the Nile many fold to just duplicate current reliable provision of irrigation and power.

Building an information infrastructure is a top priority, as a basis for making the case to both the public and to the politicians.

There will have to be a commitment to change. Both political will and an informed public perception is critical here. The potential impact of global climate change is a good example. The public either has to perceive that this is a real possibility or at least develop a sense of appropriate risk insurance about such future events. The political cost of change can be high. In most cases there are losers as well as winners. It is in this sense that water policy is like grand opera — encompassing love, hate,

greed, sorrow, and all the passions that stem from control or denial of one of the basic resources for life!

It is in the interest of agriculture to act before there is a great crisis about water use in agriculture: agriculture is best served if the crisis is averted. If a world water crisis occurs, and agriculture is seen as the major contributor to that crisis, the decision making power of agriculture over water could be taken away and given to others.

8. Concluding remarks

It was a very positive sign that there was a *great deal of agreement* among the Workshop participants on the nature and extent of the problem insofar as it can be measured today. While there are not yet satisfactory indices to measure the problem to the extent believed necessary, people are now talking the same language in describing the problem. Even those countries not yet suffering one dimension of the problem of sustainable water use in agriculture recognise the extent to which they are likely to be suffering another dimension. For example, where water is abundant and there is no quantity problem there may be a growing water quality problem that can eventually bring about its own water quantity problem. At the end of the Workshop there was a common recognition of the different kinds of water problems across the world's agriculture.

A second positive impact was the discussion by participants in areas where there was *substantial disagreement*. This discussion served to narrow the perceived area of disagreement. For example, those who believe in the economic efficacy of full pricing for water for agriculture and those who believe in important social benefits of low priced water for agriculture both gained a great deal from the intense discussion of this issue. Such a discussion forces a realisation on both sides that what is involved are important trade-offs that have to be justified. If one argues for full cost pricing one has to deal with the trade-offs involving the difficulty of pricing social concerns or full environmental benefits. If one argues for low priced water for agriculture one is then forced to deal with the question of incentives for efficient use of water. Everyone's strongly held views were tempered by that discussion. This is critically important, because trade-offs like these will have to be resolved if there is to be a more sustainable future for water use in agriculture.

The discussion of a *coherent approach* was also an important contribution of the Workshop. Most participants started from the standpoint that the problems of their country or region were unique or, on the other hand, were convinced that the particular strategy they were adopting would be best for everyone else as well. The intense discussion on the specific nature of local situations juxtaposed with universal concerns for improved efficiency in water use brought the original mind sets closer together. The delegates recognised that there is no mechanistic or institutionally coherent approach that can be applied across the board. What emerges was a common set of touchstones that are helpful guides in dealing with the problem of sustainable water for agriculture — touchstones that recognise the important trade-offs that each community, country, or region will have to make in changing the way water is allocated and used in agriculture.

As these concluding comments indicate, one of the *great strengths* of this Workshop was that it became a Workshop. This was not just a collection of papers and presentations. There was a lively discussion of real issues and different points of view expressed both formally and informally. Such understanding and appreciation for different views and approaches is critical when dealing with a problem for which there is no one "right" answer.

CHALLENGES IN THE FIELD OF WATER RESOURCE MANAGEMENT IN AGRICULTURE

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Summary

Growth in agricultural production has exceeded demographic growth during the last 30 years and the nutritional situation of the world has improved. There are however clear indications that the “green revolution” based on high-yield varieties, irrigation and high inputs in fertilisers and pesticides is stalling. Because of physical, economic and environmental constraints, irrigated agriculture cannot continue increasing its water appropriation as in the past, a fact already reflected in decreasing expansion of irrigation since the 1980s. While rainfed agriculture is still producing some 60 per cent of the global food supply, sustainability limits in the pattern of water use for irrigation have been met and much improved management of water is needed in the future. In the competition for water, improved water conservation measures aiming at increased rainfall infiltration provide an opportunity for transferring food production upstream, where runoff is generated.

Subsidised water and high-input agriculture have resulted in wastage and pollution of water resources that are needed for domestic water supply. The fact that large amounts of water are appropriated for low efficiency uses brings into the foreground the need for improvement in the way water is allocated among social strata, sectors, activities and regions in order to achieve the most worthwhile overall use across sectors in society. As water subsidies are terminated, society is increasingly willing to equitably compensate the farmer for protecting the environment and preserving the landscape, wetlands and forests. It is clear that policy and management decisions cannot be taken in isolation and integrated river basin management is often the only viable management process.

New and better adapted policies and strategies are being applied progressively, as the political and economic situation makes interventions feasible. These interventions generally go in the sense of removing subsidies to water and agriculture, re-allocating water with overall efficiency criteria, ensuring sustainability and environmental protection and using market mechanisms to achieve efficiency. Equity considerations have room in this approach through direct support targeted at individuals and not at agricultural inputs and products. Enhanced education and public information should support the process of overcoming future water management hurdles.

1. The opinions expressed in this paper are those of the authors and should not be construed as those of the Food and Agriculture Organization of the United Nations.

1. Introduction

Among the many roles of agriculture, the basic one is to produce food. Where rainfall is insufficient or unreliable, addition of water to the root zone through irrigation improves crop productivity. For the success of the crop, it is indifferent whether the optimum level of soil moisture at the root level is achieved through natural rainfall or is added by irrigation.

Agriculture is called to increase the total quantity of food it produces as the number of people living on the globe grows. A first question could be, why is agriculture at present not producing enough food for everybody? The reply is that the main reason for food insecurity and malnutrition is poverty. The broad objective of ensuring satisfaction of food and other basic needs for all is therefore closely related to a subsidiary universal objective of ensuring adequate income to the population concerned. A second question frequently raised is: Will there be enough water to allow for universal food security of the future population of the globe? The reply can be foreshadowed: enough water is available but sustainability limits have been met in various places and much improved management of water is needed in the future to overcome the straits while population stabilises.

During the 20th century the rate of water withdrawals in the world has increased much faster than population, owing mostly to irrigation and industrial development. On a rough average, 70 per cent of global water abstraction is for irrigated agriculture. The figure may be above 90 per cent in some arid countries and regions, while the percentage is less in countries that can produce food without irrigation and in countries with a strong industrial and urban water demand. Growth in agricultural production has exceeded demographic growth during the last 30 years and the nutritional situation of the world has improved. The “green revolution” made this possible. There are however clear indications that the green revolution is stalling and the rate of increase of irrigated land is levelling off.

While the renewable amount of water annually available is fairly fixed, the amount of water available per person and per year diminishes as population increases. At a time when industrial and municipal users are in competition with agriculture for water, the preservation of the aquatic environment and of valuable ecosystem services also requires that an appropriate amount of water is left and protected in rivers, lakes and wetlands.

While irrigation water is applied to improve productivity and to open for agriculture regions that do not have appropriate rainfall, rainfed agriculture, which is not in direct competition with other water uses, is still producing some 60 per cent of the global food supply. Water extracted from rivers, lakes and aquifers cannot be substituted for such uses as human consumption, municipal use and some industrial processes; in contrast, water applied in irrigation represents only a secondary, albeit very important, facet of global agriculture. Moreover, the current debate about water scarcity should not overshadow the fact that agricultural production is also constrained by excess water and that drainage is a condition to improve productivity.

2. Projecting the water supply/demand balance

Food production is by far the largest user of water. An assessment of how much water is needed to produce food for the future world population could be based on the dietary energy supply (DES) at the national level, as a proxy for future water demand. The DES varies between some 2 200 calories for poor countries (that harbour a large numbers of undernourished), to 3 500 calories for rich

countries (where sometimes obesity is a public health problem). The national food supply situation is considered just satisfactory at the 2 700 calories level, when few people are undernourished.

An estimate of the amount of water, regardless of origin, taken up by the crop plant to produce a selection of basic crops is given in Table 1. The same table contains estimates of the amount of water required to produce chicken and beef. An estimate of the water needed to produce an average balanced annual diet for one person could be based on the figure, 2 000 m³ per person per year. World diets richer in meat, particularly beef, would however project significantly higher water demand (Klohn and Wolter, 1997).

Table 1. Amount of water used to produce foodstuff

Foodstuff	Litres of water per kg
Potatoes	500
Wheat	900
Sorghum	1 100
Maize	1 400
Rice	1 900
Soya	2 000
Chicken	3 500
Beef	20 000 — 100 000

Feeding the current world population of 5.8 billion effectively requires 11 600 km³ of water stemming both from rainfall and irrigation. Furthermore, accepting that some 40 per cent of food is currently produced under irrigated agriculture, and that irrigated agriculture on average takes 40 per cent of water from irrigation, one may conclude that irrigation effectively uses some 1 850 km³ of water for food production while 9 750 km³ of water inputs to food production stem directly from rainfall. The 8.2 billion population projected for 2025 would then demand 16 400 km³ of water, or 15 per cent of total global rainfall, to produce the required food.

On the global water supply side, runoff in rivers and lakes or underground amounts to some 40 000 km³ or 35 per cent of total rainfall. About 12 500 km³, or 30 per cent of total runoff, is considered to be annually accessible in the given economic context. Some 5 000 km³ of accessible runoff are already appropriated, much more than the water effectively used for food production. Technically, more water can be mobilised by harnessing remote rivers, capturing floods, melting polar ice or desalinating sea water, but at a steeply increased cost in terms of finance, energy and environment.

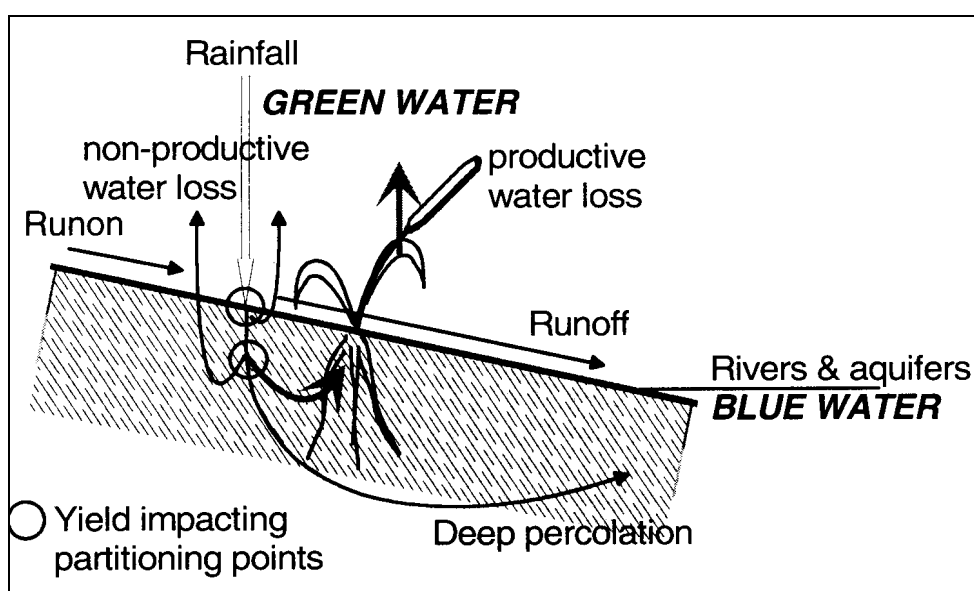
Within the conceptual limits of the given assumptions, this finding confirms other global indicators that point to unsustainability of the current global trend of water use. There is not much unused suitable land left for horizontal expansion of agriculture, and demographic growth as well as scarcity of funds is forcing policies and practices that result in better use of irrigation water and rainfall, supported by more productive cultivars in a more technical agricultural environment.

Ultimately, however, whatever cumulated and averaged realities the global statistics reflect, water policies and practices are devised and implemented at the national or local level where the situation may vary from dire water scarcity to pervading humidity and flooding.

3. Local use of rainfall versus generation of runoff

Figure 1 is a close-up that shows the partitioning of rainfall at the point it hits the ground. The surface runoff and deep percolation that collects in water bodies is sometimes called “blue water”, while “green water” is the productive or non-productive water loss that joins the atmosphere. Farmers dissatisfied with the quantity and opportunity of natural rainfall invented irrigation, which is but a way to reclaim runoff, seen as unproductively sunk into the oceans, and lead it to the root system of the crop. There are still other ways of intervention possible at this level; for example, soil additives that increase water storage within the root zone.

Figure 1. Partitioning of rainfall as it reaches the ground



Source: Rockstroem and Tilander, 1997.

In a market situation, irrigation tends to lose out against rainfed cropping because there is a cost to irrigation in pumping, storage, conveyance and system maintenance, while rainfall is free. For this reason, once irrigation water is not subsidised and confronted with the market, it tends to become confined to speciality niches such as high value products that benefit from the sunny arid climate and from production off the rainy season. In the competition for water, food production may be transferred upstream, where runoff is generated, through improved cropping and tilling practices and other water conservation measures aiming at increasing infiltration while decreasing runoff with consequent costs for e.g. lost energy production. Already in some situations, downstream water users have complained about larger numbers of farmers applying better farming practices in upper catchments.

While water scarcity is dominating the current debate, it should not be forgotten that, to improve farm productivity, the water management problem to be faced sometimes is drainage, that is, leading water away from the root zone. In such cases, downstream consequences may include undesired flooding and increased risks of environmental pollution.

4. Issues in water management for agriculture

Agricultural policy and water management do not stand in isolation

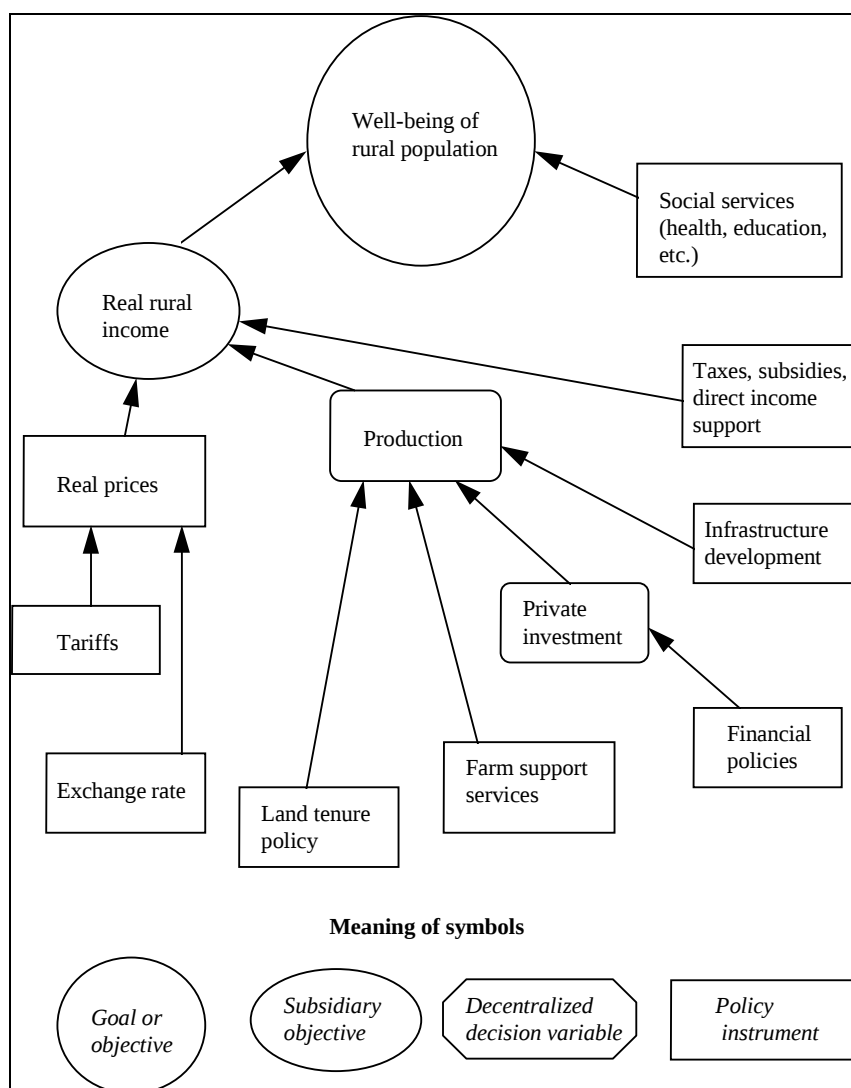
As agriculture is a heavy user and a potential polluter of water, water policy strongly depends on agricultural policy. In turn, agricultural policy is subordinated to national objectives, which may be served also by non-agricultural uses of water. Figure 2 shows possible relationships between overall and subsidiary objectives, decentralised means and government policy instruments. In this case, well-being of rural population is a main goal which depends on a subsidiary objective: real rural income, on decentralised means and on a policy instrument: social services available to rural people. Real rural income, a subsidiary objective, depends on real prices, a policy instrument subsidiary to tariffs and the exchange rate; on production, which is a decentralised decision variable, and on other policy instruments such as taxes, subsidies and direct income support. Agricultural production in turn depends on a number of direct and indirect policy instruments, such as infrastructure development. National water strategy and management cannot be isolated from national development goals, subject to subsidiary water objectives.

Environmental performance of agriculture

At a time when global demography calls for intensification of food production, intensive, high-input agriculture in industrialised countries, often associated with highly subsidised water resulting in massive waste, is found to be environmentally non-sustainable and subject to significant policy changes. Water pollution stemming from inappropriate practices in the use of chemical fertiliser and pesticides, and from other intense forms of production such as livestock feedlots, has led to groundwater contamination that is highly damaging for domestic water supply. Similarly, over-use of groundwater has led to quality degradation by saline intrusion in heavily populated coastal zones. Alternative sources of water are often not available, treatment is beyond technical and economic reach and the recovery period of contaminated aquifers can be very long, in the hundreds of years. Thus, water pollution and over-exploitation leads to direct economic costs to society for water treatment and development of alternative supplies, while degradation of ecosystems and declining public health become important social and environmental externality costs and a threat to environmental sustainability and social security. In developing countries these effects, which are directly related to the increase in population density, normally get only a low level of attention. In the industrialised countries, however, the social and environmental externality costs for water pollution tend to be a main issue. No wonder therefore that societies take curtailing action on agricultural subsidies that have resulted in costly pollution. Moreover, in affluent countries the public reckons that a decreasing part of the family budget is used for food, and that the agricultural value in food is relatively low: more than 80 per cent of the shelf cost of a food item may be caused by non-agricultural added value, such a conditioning, packaging, storing and promoting the brand. Thus, society becomes increasingly willing to compensate the farmer for protecting the environment and preserving the landscape. For example, it has been reported that Swiss mountain farmers income is based 30 per cent on farm income and 70 per cent on direct income subsidy, based on the nationally

accepted need for preservation of the farming landscape. It can generally be stated that subsidies will continue for reasons of equity and services to the environment. but will focus on direct support rather than general input or product subsidies.

Figure 2. Relations between objectives, decentralised decision variables and instruments in agricultural policy



Ecosystem services, wetlands, forests and biodiversity

As the protection of the environment is becoming one of the major goals of civil society, awareness of the direct and indirect benefits of ecosystems services is increasing among the general public and at political levels and the protection of wetlands, forests and biodiversity is moving up on the agenda. Ecosystem products do have a significant value and can represent an important source of income for rural and urban communities. Wetlands, for example, which exhibit large diversity in size and shape,

are complex, dynamic ecosystems that help and protect rivers and lakes by storing nutrients and reducing sediment loads. Considerable progress needs to be made in the science and art of wetlands development planning and management to conciliate production and conservation objectives. Many developed countries have already drained and developed for agriculture a substantial part of their wetlands, while in developing countries, wetlands (valley bottoms, dambos) represent an important agricultural reserve prone to development as demographic pressure pushes the agricultural frontier. A number of governments have subscribed legally binding conventions or treaties that protect wetlands.

A sometimes overseen facet is that in a number of countries, the management of drained land is a major challenge for agricultural and water policy. The management objectives are twofold: restoring and maintaining drained systems to functioning conditions, and controlling agricultural pollution from drained land areas, two costly undertakings that require major infrastructure, with high social significance for rural welfare and environmental protection. In the restructuring of the agriculture sector, some of these lands may be used in intensive, high-input agriculture, while a part of the sector may turn to low intensity agriculture, landscape maintenance agriculture, runoff regulation and erosion control. Preservation of forests, landscape and traditional agricultural skills may tend to come under new lines of direct public support.

Water allocation efficiency and water use efficiency

Wherever water is scarce, whether because of natural shortage or inadequate allocation, ways need to be found for its best possible use. In this respect, two different realms for exercising efficiency are recognised. One is allocation efficiency which addresses how water should be allocated among social strata, sector, activities and regions in order to achieve the most worthwhile overall use across sectors in society (Lundqvist and Gleick, 1997). Competing demands for water have various costs and benefits associated. If large volumes of water are allocated to a sector producing low value, the total amount of value generated in society will be low. For example, it has been reported that while 70 per cent of water resources in Israel are devoted to agriculture, farming only generates 3-5 per cent of the GDP (Shuval, 1997). This is an interesting case because the Israeli agriculture uses water very efficiently in a technical sense. Allocation efficiency has been extensively discussed in the 1990s with a milestone set at the Dublin Conference: the fourth Dublin principle states that water has an economic value in all its competing uses and should be recognised as an economic good (ICWE, 1992). Opportunity costs are becoming increasingly important and need to be considered. Benefits from water need to be seen in a wide context and include such aspects as employment, production, poverty alleviation, public health and environmental values.

Another form of efficiency applies to performance in accomplishing a specific goal without using more water than necessary; for example, in efficient irrigation the water abstracted is applied to crop production and to preserving the salt balance in the soil, while non-productive evaporation, deep percolation and other losses are minimised. Modern irrigation technology provides a panoply of techniques and tools for accurate application of water to the roots according to the requirements of the crop. Such techniques do not need to be expensive or difficult to apply but they do require capable, diligent farming.

Farmer skills and public information

With increased financial and environmental responsibility in addition to technical skills, the farmers of the future are expected to exercise increased management capacities. The process will be

supported by the advent of a new generation of farmers exposed to a more diversified education. This trend should be reflected in broadened curricula and enhanced thresholds in farmer training and managerial capacity. Attention is required to the fact that, as intensive production agriculture continues shifting from a system based on farmers to one based on agribusiness, land tenure tends to be separated from farming operations. This trend may result in decreased commitment to sustainable land use and practices. Not less important, public awareness is fundamental for future sustainable water use. There is consequently a need to further develop the quality of information on water issues and the level of understanding by the public of the multiple issues and facets involved in water management.

Water in agricultural trade

At a time when an increasing number of countries slide away from food self-sufficiency, national food security becomes more dependent on trade. In this respect, some countries are self-reliant, meaning that they are able to generate sufficient foreign exchange to cover their food bill, but not self-sufficient, meaning that they do not have enough water, in the form of either rainfall or runoff, to produce domestically all the required food. The global market is somehow expected to take care of the transfer of food from the regions able to produce surplus to supply the countries in the deficit regions with agricultural products. For example, a recent FAO study estimated the net import of food for each country in the Near East region and transformed it into water equivalent (FAO, 1997). The results show that the food imports of the region represent a volume of water comparable to the flow of the Nile at Aswan. The policies of trading blocks and affluent countries have consequences in poor countries because of the potential for social disintegration and instability spilling over into large regions. In this aspect, there is a connection between water scarcity and national security (Appelgren and Klohn, 1997).

5. Conclusions

Past trends in the appropriation of water resources for human use, and in particular for irrigated agriculture, are not sustainable. The consequences of these trends, generally characterised by excessive water use owing to subsidies, have been perceived at various quarters in terms of water pollution, water scarcity and overdrawn aquifers. The process of adjustment and corrective action has already been initiated but the unsustainable water management question has as yet not been universally solved. New policies and strategies, better adapted to local water availability, climate and physical environment and to the priority needs of the population, are applied progressively, as the political and economic situation makes interventions feasible. These interventions generally go in the sense of removing subsidies to water and agriculture or replacing them with well-directed direct support, re-allocating water with overall efficiency criteria, ensuring productive sustainability and environmental protection and using market mechanisms to achieve use efficiency. Water policy and strategy is eminently a national matter; however, attention needs to be paid to the international implications that may ensue from the decisions of major trading blocks. As a consequence, a particular cause of concern in a global context are those countries that face serious water management issues but do not have the economic and technological resources to appropriately deal with the problem.

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IRRIGATED AGRICULTURE AND THE ENVIRONMENT — PROBLEMS AND ISSUES IN WATER POLICY

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Summary

A remarkable consensus has taken shape over recent years³ on how we should manage water resources in general and in irrigated agriculture in particular. However, there is still a long way to go until consensus becomes reality. Efforts in recent years point where we were wrong, and where should we aim at. Having a direction to go, we need now to identify both the optimal path and to determine the pace of progress.

Clearly, a sense of urgency for more responsible stewardship of water resources has been awakened. However, the irrigation sector is slower than other water use sectors in recognising the need for policy reform that should address more appropriately the role of irrigated agriculture in producing greater amounts of food and its responsibility for keeping the health of environmental resources.

A notion that prevailed in early years of development, that irrigated agriculture and the environment can not share scarce water resources, does not hold any more. On the contrary, experience in many unfortunate places around the world demonstrate that irrigated agriculture and the environment must share scarce water resources in order to benefit from each other. Proper guidance by supporting policies will enhance such symbiotic relationship.

2. Valuable comments were provided by John Briscoe, Gershon Feder, Alex McCalla, and Lambert Smedema. The views expressed in this paper are those of the author and should not be attributed to the World Bank.

3. For example, the Ministerial Meeting in Noordwijk in 1994 agreed on the need to shift from the old supply-driven programs to a new, demand-led agenda for water supply and sanitation. At the IWRA meeting in Cairo that same year, the World Bank presented its policy for comprehensive water resource management grounded in the principles of Dublin and Agenda 21. And at the Stockholm Water Symposium in 1994, there was widespread agreement on moving from segmented to comprehensive strategies, from curative to preventive interventions, from incremental to strategic investments and from piloting to mainstreaming innovations (Serageldin 1996).

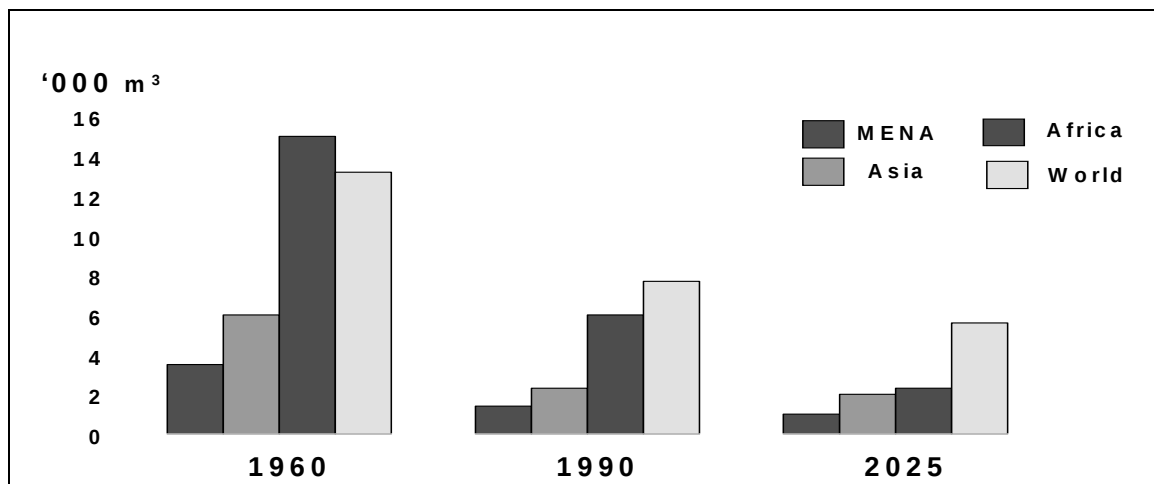
1. Introduction

Many believe that the world faces a crisis in the availability (both in terms of quantity and quality) of the planet's water resources because, unfortunately, it is not managed appropriately as the most precious resource should be.

In recent decades, water withdrawals have been increasing at a rate of 4 per cent to 8 per cent per year mostly in developing countries. Of the total amount of 3 240 cubic km of water withdrawal in 1992, 70 per cent was used for agriculture, 20 per cent for industry, and 10 per cent for domestic consumption (World Resources Institute 1994). Water is one of the most valuable resources on earth, and only a fixed amount of this resource is available. While per capita availability of water is declining in most countries, water is being misused. Forty to sixty per cent of the water delivered by utilities is lost to leakage, theft, and poor accounting. Of the 70 per cent of the world's water used for irrigation, half is lost to seepage⁴ and evaporation. In addition in many parts of the world water quality in groundwater aquifers and other surface water sources is threatened by pollution resulting also from irrigated agriculture, thus reducing actual availability of water for consumption. With its fixed available amount and quality degradation problems, and with increased consumption (Figure 1), allocation of scarce water resources among sectors and users does often necessitate setting priorities and regulations, which imposes a continuously increasing importance to optimise management of the resource from a total perspective.

Lately, awareness has increased and water policy issues are on the agenda of many countries as well as development institutions (World Bank, 1993; ODA, 1993; FAO, 1995; FAO, 1996; ADB, 1996; SIDA, 1997; SEI, 1997). While one can point to many successes, policies are still unsustainable from several perspective—social, economic or environmental.

Figure 1. Regional per capita availability of water



MENA = Middle East and North Africa Region.

Source: Serageldin (1996).

4. There are some who claim that seepage is not considered lost water (Seckler 1996). Taking into account return flows, agriculture, municipal and industry consume 93 per cent, 3 per cent and 4 per cent, respectively.

The purpose of this paper is to highlight the problems and challenges associated with the world's growing population and its needs for food and water on the one hand, and to suggest guidelines for meeting these needs in a sustainable way, on the other hand. The paper will focus on policy solutions to irrigated agriculture as a major vehicle for increased food production and at the same time a primary cause for environmental degradation. The next section reviews the role of irrigated agriculture in food production and in water related problems. Then risk to agricultural development and environmental sustainability are discussed. Section four addresses the future challenges the irrigation sector is faced with relation to the environment and to food production needs. The fifth section identifies issues and directions for potential policy reform. And the final section summarises the paper.

2. Irrigated agriculture and water-related problems

Of all water-use sectors, irrigation is the most important. Irrigation has formed the foundation of civilisations for millennia. Over the last 30 years, irrigation has contributed a great deal to the increases in food production that have made it possible to feed the world's growing population. Irrigation has been instrumental in keeping basic food staples affordable. And it has helped reduce rural poverty, especially in the countries of South and South East Asia. Although there are still great disparities in access to food, the estimated food availability per person in the world has increased by 17.5 per cent and by 27.6 per cent in the developing countries between 1960 and 1990 (IFPRI, 1995).

At the same time agricultural production accounts for a large and growing share of water pollution by fertilisers, pesticides, and in some cases, heavy metals. For example, Ribaud (1989) estimates that in the U.S., runoff of agricultural chemicals causes an annual US\$9 billion damage to surface water (lakes, rivers). Local and federal water quality agencies in many countries face substantial difficulties in finding long-term optimal policies to control such problems.

The increasing number of problems in water resources management stem, in large part, from problems in irrigation. While there have been many notable efforts at reform, in many countries water in irrigation is still mis-allocated and wasted, farmers are not well-served by water supply agencies, and, as a result, land and water are being degraded.

As the largest user of water, the burden of reform and the challenge of innovation and change falls mainly on the irrigation community. Governments have a particular responsibility because the problems in irrigation are largely the result of government policies that fragment institutions responsible for water management, neglect appropriate pricing and financial discipline, and discourage beneficiaries, non-governmental organisations and the private sector from meaningful participation in water management.

Irrigation has been the largest recipient of public agricultural investment in the developing world. Over the last 30 years, billions of dollars have been spent to assure water supplies, raise yields and improve rural livelihoods. For example, since 1950, the World Bank has invested some US\$31 billion (Table 1; Figure 2) in irrigation (in 1996 real US\$), which leveraged an additional US\$53 billion from partner countries and co-financiers (Serageldin 1996). However, the Bank's irrigation portfolio has been reduced by half in terms of the number of projects under implementation during the last decade. The portfolio⁵ remains concentrated in a few large countries; India, China,

5. As of 8/96, based on World Bank (1996).

Brazil, Mexico and Indonesia account for 40 per cent of all projects and 67 per cent of total commitments. East and South Asia together account for 56 per cent of all projects and 63 per cent of all commitments. Africa's share has continued to decline and currently stands at 1 per cent of total commitments.

Given its substantial share in the Bank's portfolio and being central to development and environmental sustainability, irrigation water was an important part of the 1993 World Bank water resources management policy.

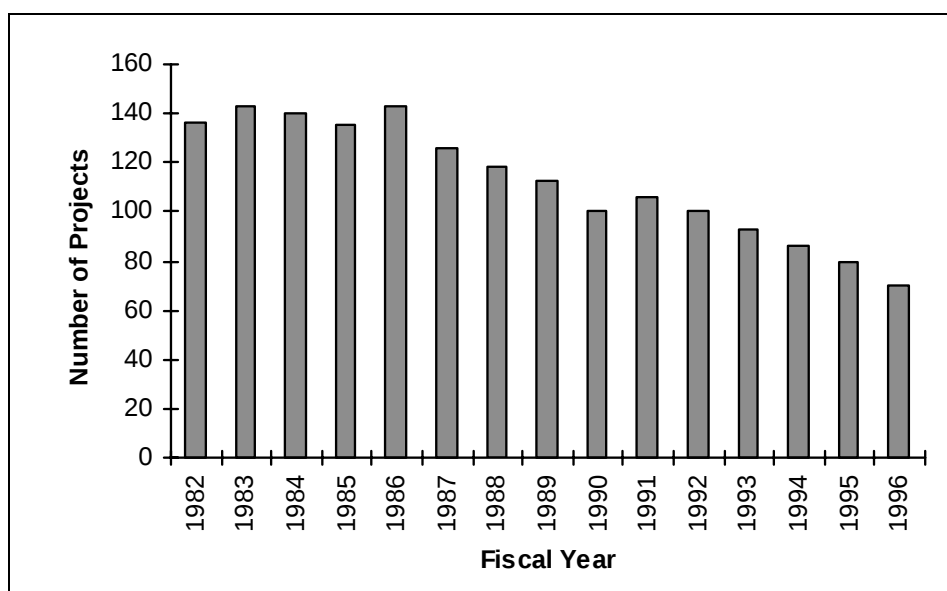
Table 1. Historical bank-supported irrigation portfolio

<i>Region</i>	<i>Number of Projects</i>	<i>% of Total</i>	<i>Total Commitment (nominal US\$ M)</i>	<i>% of Total</i>	<i>Average Commitment (nominal US\$ M)</i>
Africa	60	15.7	1 065.2	5.1	17.8
East Asia	88	23.0	5 697.8	27.4	64.7
South Asia	117	30.6	7 233.6	34.8	61.8
Europe & C. Asia	29	7.6	1 554.4	7.5	53.6
M. East & N. Africa	40	10.5	1 990.1	9.6	49.8
Latin America	48	12.6	3 241.0	15.6	67.5
Bankwide Total	382	100.0	20 782.0	100.0	54.4

Note: All dollar amounts in nominal US\$ millions.

Source: World Bank, 1996.

Figure 2. Number of active projects during Fiscal Years FY82 to FY96



Source: World Bank, 1996.

World Bank water resources management policy

At a time of scarce public financial resources and declining aid budgets, as well as deteriorating water and other environmental resources, it is urgent that governments ensure their investments are put to optimal use and that water and other environmental resources are protected. The World Bank in its 1993 Water Resources Management Policy Paper (World Bank, 1993) set forth a series of principles to deal with the development and management of water resources in general and with irrigation water in particular. The policy calls for:

- Dealing with water in a comprehensive analytical framework.
- Promoting reforms in institutional and regulatory systems.
- Incorporating incentives for efficient use of water.
- Promoting water conserving technologies.
- Addressing poverty alleviation considerations.
- Promoting decentralisation of water public water services.
- Promote participation of different interest groups.
- Including environmental protection considerations.
- Allowing capacity building of agencies and individuals.
- Advocating for international co-operation over shared water courses.

These principles will be discussed in this paper vis-à-vis relationship between irrigated agriculture and the environment.

3. Irrigated agriculture and risks to sustainability

Clearly, the achievements of irrigation in ensuring food security and improving rural welfare have been impressive. However, past experience includes also records of irrigation related problems and failures, which put the sustainability of its achievements seriously at risk. There are several reasons for that risk, some of the reasons are subjective, and related to the performance of the sector, they include (Plusquellec, 1997):

- Wasteful use of water.
- Irrigation systems which are not responsive to the needs of the farmers.
- Environmental destruction.
- Low productivity.
- Deteriorating capabilities of key institutions.

- Inadequate investment in drainage and in research.

Other reasons for potential risk associated with irrigated agriculture are related to global conditions, and are discussed hereafter.

Multiple claims

There are multiple and growing claims for water resources, because of growing population, migration from rural to urban and metropolitan areas, improved standards of living, and industrial growth. Being the biggest user of water, the demands on the irrigation sector to meet the growing needs for water have escalated dramatically. In developing countries, more than 80 per cent of water resources is used for irrigation. In some countries the ratio is even greater than 90 per cent. Many countries are already under pressure to re-allocate water used for irrigation to other uses.

Growing urban populations will increase the demand for potable water and for treatment of wastes. To provide for the added population will require the same amount of water which would be needed to irrigate 25 million hectares — around 15 per cent of the total irrigated land area in developing countries (Yudelman, 1993). Even more is needed if the basic water and sanitation needs of existing populations are to be met. Today about one billion people in the developing world lack access to potable water, and 1.7 billion do not have adequate sanitation. Urbanisation and industrialisation will also add to the demand for energy and hydropower, putting further stress on water supplies.

As estimated in Feder and Keck (1994), domestic and industrial water use, affected by per-capita GNP, population, and share of urban population, will grow between 4 to 6 fold in Asia between 1995 and 2025. Although this is a very big relative increase, absolute values of decreased water availability to irrigation are relatively moderate in that region, given that the share of water resources used presently is less than 20 per cent of the total available resources. The picture in water scarce regions is more alarming. For example, a similar growth in domestic and industrial water use in Middle East and North Africa countries implies a decline in absolute amount of water used by agriculture.

With growing awareness of environmental needs, with increased urbanisation rates, and declined agricultural profitability, pressure to inter-sectoral reallocation of scarce water resources may increase inter-sectoral and international disputes.

Rising development costs

While demand is growing, the costs of developing new water supplies is increasing. The lowest cost, most reliable and most environmentally resilient sources of water have already been developed in most countries. For example, according to Howitt and Vaux (1995) actual marginal cost of developing surface water in California has reached US\$0.24 in 1980 constant dollars (see Table 2). As can be seen from the table, expanding the capacity of the system from 7.4 to 9.9 billion cubic meter per year is associated with almost tripling the marginal cost. Further more, today, costs of Bank-financed repeated water supply and irrigation projects typically run 2 to 3 times higher than the last project.

The real capital costs of new irrigation have risen, on average, by between 70 and 116 per cent per hectare over the 1980s because of a growing shortage of well-sited, low-cost options for development.

The average cost to develop a hectare of irrigated agriculture is between US\$8-10 000 for surface schemes, and many irrigation systems around the world cost substantially more than that. In India and Indonesia, real costs of new irrigation projects have doubled over the past 25 years. In Thailand and the Philippines, cost have increased 40 and 50 per cent, respectively (Serageldin, 1996). Costs of irrigation will increase even further when adequate drainage is included as an essential part of investments and the social costs of resettlement from storage schemes is fully incorporated into projects. The rising real costs per hectare of irrigated agriculture or per unit of new water resources are among the most important causes of declines in investment in irrigation in India and China.

Table 2. Marginal cost of surface water in California (1980 constant dollars)

<i>Annual Yield (billion cubic meters)</i>	<i>Cost (US\$ per cubic meter)</i>
1.2	0.022
2.5	0.032
4.9	0.064
6.2	0.081
7.4	0.097
9.9	0.243

Source: Modified from Howitt and Vaux 1995.

Declining water and soil quality

Water quality is becoming increasingly degraded as urban populations and industry grow and as agriculture intensifies. Already, human consumption of polluted water is the principal cause of many health problems, causing a billion people to fall sick every year and the deaths of almost two million children a year. In addition to direct and indirect health problems associated with water pollution due to irrigated agriculture, there are soil productivity problems that reduce the stock of productive land (Table 3) and indirectly affect people by reduced availability and quality of food product.

Table 3. Irrigated land damaged by salinisation, top five irrigators, mid-1980s

Country	Area Damaged (Million ha)	Share of irrigated land damaged (%)
India	20.0 ^a	36
China	7.0	15
United States	5.2	27
Pakistan	3.2	20
Soviet Union	2.5	12
Total	37.9^b	24

^aIt should be mentioned that according to GOI (1991) only 3.3 million ha of land are damaged due to salinity.

^bAccording to FAO (1990) 20-30 million ha in the world are seriously affected by salinity.

Source: Postel (1989).

Water and soil salinity and the resulting damage to crops is an acute problem. 2-3⁶ million hectares of irrigated land are affected each year to salinisation (Serageldin 1996). Many irrigated basins in the arid areas are far from an acceptable salt sink into which drainage water can be disposed. Investments in outfall drains and water treatment facilities have been neglected. According to IFPRI (1994), about 24 per cent of the world's irrigated land is affected by salinisation to varying degrees, severely reducing the productivity of that land. The major areas of concern are the Indus, Tigris, and Euphrates river basins where continued salinisation could threaten regional food security. In many areas where there is excessive use of fertilisers and pesticides, drainage water also has levels of nutrients and toxins that exceed the assimilative capacities of the receiving water. In the past, degraded land was "recovered" through an equal expansion of irrigated area, but expansion is no longer possible because of the high costs of transportation, land clearing and development, land rights and more limited availability of water. The result is that the net rate of land expansion has slowed from 2.7 per cent over the last half century to less than 1 per cent today.

Aquifer depletion and pollution are also serious problems in many parts of the world. In many places groundwater has been polluted or is seriously at risk from over-exploitation and contamination by pollutants and salt water intrusion. Irrigation schemes also often divert water from downstream areas that support sensitive water-dependent ecosystems, including wetlands, which are then not able to fulfil their valuable functions of filtering pollutants and supporting biodiversity. Several examples can be provided, but the most acute one is the Aral Sea region in Central Asia (Box 1).

The impact of water withdrawal and agricultural pollution on the Aral Sea region has been devastating. Water level has dropped from 53.3 to 39 meters above sea level, and salinity content tripled from 10 to 28 gram/litre between 1960 and 1989. If no action is taken, it is expected that the water level will fall to 32 meters and the salinity content will increase to 65 gram/litre in the year 2000.

4. Challenges

The irrigation community is faced with several challenges to be addressed in the short- and the long-run. We need to remember that food production has to be doubled between now and the year 2030, which must be produced with less available water and with more strict rules of meeting environmental health. Several of these challenges will be discussed here in more details.

Food production

Irrigation performs the essential task of meeting the basic food requirements of billions of people in the world. Irrigation provides 60 per cent of rice and 40 per cent of wheat production in the developing countries (Crosson and Anderson, 1992). It provides the bulk of food supplies for China, India, Pakistan, Indonesia and other countries in Asia where the large majority of the world's people live.

6. According to FAO (1990) 1 million ha per year are affected by salinity.

Box 1. Aral sea: man-made changes and their devastating effects

In the 1960s, resulting from Soviet government irrigation development projects, water has been withdrawn from the Amu Darya and Syr Darya before their discharge into the Aral Sea, and has been conveyed to remote desert areas of Kazakhstan and Uzbekistan. The water has been used mainly for irrigation of cotton and rice using very inefficient irrigation technologies. This has resulted in:

- Falling water level in the lake, and reduction in its area.
- Increased salinity levels of the lake's water.

The marked reduction in the lake's area has resulted in significant climatic changes in the region including lower temperatures, lesser amounts of snow in the mountains, reduced snowmelt, and less river flow affecting the irrigated agriculture and the recharge to the lake. Additional effects have been wind erosion, and deposition of salts from the lake bed, that have caused damages to crops, power lines, concrete structures, and land fertility, and severe health problems of the population in the region. Groundwater levels of aquifers in the basin have been lowered and their water quality has deteriorated significantly. Forests areas have declined, and in many places disappeared. Navigation in the lake is impossible now, and fish catches from the lake are null. All the fish for the canning industry, once from the Aral Sea, is imported from other regions.

Source: Ayres et al. 1997.

The increase in food production is largely the result of the transformation from extensive to intensive agriculture made possible by the “green revolution”. This came about by the development and diffusion of modern high yielding varieties of seeds; by the development of low cost industrial methods of manufacturing nitrogenous fertiliser and its widespread use, especially in Asia; and by the very large increase in irrigated areas. The gross area served by irrigation increased from 95 million ha in 1940 to 253 million ha in 1989 (World Resources Institute 1994).

Between 1960 and 1990, the combination of improved varieties, greater use of fertiliser and extended control of water raised yields of cereals by 117 per cent in Asia, 70 per cent in Latin America and 45 per cent in Africa — about 2.6 per cent a year, higher than average world population growth (Yudelman, 1993). Today, one-third of the world's food harvest—worth more than US\$100 billion—and more than 50 per cent of the world's grain production comes from irrigated agriculture. Yet, irrigated agriculture accounts for less than 20 per cent of the world's cultivated land.

Poverty reduction

As a major producer of food and source of agricultural inputs, irrigation plays an important role in the effort to fight poverty, increase rural welfare and reduce the number of people migrating to urban areas. Even if they do not grow their own food, more than 70 per cent of the poor in the world are still rural based and depend on rural employment and income created mostly by agricultural activities.

Sustainable development and environmental well-doing

The water in the world's lakes, rivers and streams supports a wide range of uses. Actions to better manage these valuable resources in a sustained manner, have to be taken into consideration due to the high levels of direct and indirect pressure on these resources from rapid population growth, industrialisation, and the growth of irrigated agriculture which are threatening their capacity to provide their enormous and varied benefits.

In addition to the quantity aspect, the quality aspect of water and environment is important as well. Since irrigation is a nonpoint source pollution activity, associated also with high level of negative externalities both within and between water catchments, certain measures to address the special nature of irrigated agriculture will need to be considered in crafting future policies. Clearly there is a problem of producing more food to feed more people, and to do it with less available water and under more strict regulations that insure a certain level of sustainability of the world's natural resources.

5. Outline for reform

Irrigation has been slow to adapt to the realities of a resource-hungry world. The 80 per cent of available fresh water that is used for irrigation in developing countries is almost twice as much per hectare as that of the developed countries and produces only one-third of the developed country crop yield. Because presently both the higher level of water quantity and the lower level of yields per unit of land or water the potential for improvement is high.

Clearly, a new approach is needed. Irrigated agriculture will need to gradually become more accountable for environmental degradation (internalising the negative externalities associated with irrigation water), in particular the degradation of water quality through contamination by salts and agro-chemicals. Stronger regulations will be required along with economic incentives, in addition to conflict resolution mechanisms to arbitrate between conflicting interests.

Policy issues

A new approach calls for new policies. First and foremost, irrigation should be placed within a water resources policy framework that takes account the future needs of other water use sectors, including the environment. It should be recognised that any irrigation-related policy affects the relationship between the irrigation sector and other sectors. In particular, irrigation and the environment via both quantity and quality dimensions.

Irrigation-water policies should be formulated (using principles in the 1993 Water Resources Management Policy framework that was presented earlier) in the context of a comprehensive framework. Such framework should recognise the interactions among various elements comprising the water catchment (which is a reasonably self-contained hydrological system) and allows cross sectoral and environmental considerations to be incorporated in the design of investment programs. Within this framework, there should be consistent rules and regulations and co-ordination among agencies responsible for water services. International co-operation for shared basins should be essential elements of this framework.

New policies should treat water as an economic good⁷ in order to provide actual and potential users with appropriate use incentives. For economic efficiency *per se*, water should be priced at its opportunity cost: its value in the best alternative use, and serve as a signal for efficient use by various users. However, social and traditional considerations, as well as practical issues of implementation, must be taken into account, in the process of pricing of water. In most developing countries, water for irrigation is heavily subsidised for various reasons. Farmers have little incentive to grow water-sensitive crops or to conserve water. Governments tend to allocate water on political and social grounds rather than on economic criteria. With recent increased awareness countries are beginning to realise the need for charging appropriately for the costs of services to supply demand, and recognising the value of water in alternative uses (Dinar and Subramanian 1997).

One of the problems with pricing irrigation water is the difficulty of measuring the volume of water each farmer receives. Alternative mechanisms can be promoted and tried. Among these alternative mechanisms are the user-based allocation rules such as cost recovery based on water deliveries to an entire village or to a water user association. Limited experience with user-based allocation suggests that under appropriate set of incentives, this might be a preferred water pricing mechanism, achieving higher efficiency than the traditional non-volumetric water pricing mechanisms.

Where farmers feel that water pricing takes away an economic rent they perceive to be an acquired right, they might be encouraged to trade their water via water markets. Based on mounting empirical evidence from around the world (Easter *et al.*, 1998; Simpson and Ringskog 1997; Thobani, 1997) markets for water are viewed by many, as able to induce efficiency and benefit both sellers and buyers. Therefore, government should encourage trading in water subject to regulation that take care of equity and environmental amenity issues.

Finally, where governments tend to justify subsidies to irrigation on the grounds that farmers are required to sell portions of their production to government agencies at pre-determined prices, reforms in water policies should be associated with marketing reforms in the agricultural sector, especially in commodity pricing and trade (McCalla, 1994; Ingco *et al.*, 1996).

A fundamental shift in the way that water resources development is considered is necessary. This entails a shift from looking to construction as a means for solving water needs to looking to improved management as the means for solving such needs. The focus on water resources management to solve a country's water resources problems is now viewed in qualitative as well as quantitative terms. This view introduces concerns about the efficient use of existing resources and the need for exploring ways that new mechanisms might enhance the incentives of water users to use water more efficiently.

This change from a "construction" to a "management" approach to solving a country's water problems alters the basic nature of assistance required by the water manager. Thus, the goal of achieving substantive improvements in water-use efficiency and the improvement of water quality presupposes detailed knowledge as how water is presently used, conditions of water supply, accurate and timely forecasts of meteorological events, alternative institutions for water management (e.g. basin planning organisations and water markets), economic incentives for efficient water use, and conditions requisite for their effective operation. Also presupposed are means of identifying information needs of individual water users and how such information can be made accessible to them in a timely manner. Generally, developing countries have neither the facilities nor the trained

7. See Briscoe (1996, 1997) for a detailed exposition of the concept.

personnel required to achieve this goal. Thus new generation of water-related projects at the Bank necessitates training of water managers to develop skills and to use information appropriately.

Management

The proper management of irrigation systems and the delivery of water services determines the degree to which farmers can control the application of water to their crops. That application is the most important determinant of crop yield and, in many locations, the determinant of environmental pollution levels.

Proper management of irrigation water needs to be seen as a combination of efforts at the field level and at the water source and delivery levels. Management of irrigation systems and delivery of water services to farmers is characterised by an excessive reliance on government. In many countries, the government's operational capacity has been stretched to the point that it can not provide an adequate service to water users. Public irrigation bureaucracies must recognise that they cannot and should not do everything. Experience demonstrates that decentralised service delivery can break the vicious cycle whereby service declines and farmers are less willing to pay.

Therefore, policies should encourage more decentralised irrigation-provision services. The idea behind Decentralization is to divide the system into several sub-systems or operational levels with clearly defined interfaces, where water can be measured and controlled. Each of the operational levels, technically capable of providing reliable, timely and equal water delivery, provides an agreed upon level of service to the next lower level. In turn, each lower level compensates the next upper level for the service received, thus creating a financially autonomous system and making all levels of the system accountable for their performance. For example, countries such as Mexico, Turkey and Colombia are achieving better-quality service by decentralising the responsibility for delivering water to local governments and transferring operations and maintenance functions, especially at the level of the secondary and tertiary canals, to water user associations and farmers.

Decentralization will mean that some responsibilities will be turned over to private actors. However, it is important that public agencies recognise where and how they will maintain a role, and what should this role be. Certainly, public agencies should continue to hold responsibility to issues such as initial allocation of water, regulation and monitoring (e.g. water quality). And the assignment of operation and maintenance responsibilities can vary widely among projects — many successful schemes are fully owned and operated and maintained by private or co-operative organisations (including farmers) while others are government owned and operated to the farm gate. Public agencies are probably better at operating and maintaining large, multipurpose systems. There will be many situations in which farmers with financial responsibility for O&M will wish to contract for O&M from public agencies. What is important is not so much who does what but that there are clear lines of authority and accountability, where every right, task and responsibility (from water rights to service definition and authorisation to delivery, payment and regulation) is assigned to someone and agreed to and understood by all.

Technology

The rapid expansion of public irrigation infrastructure in the second half of the Twentieth Century has been accompanied by an unsuccessful attempt to provide all the necessary institutions and incentives to make it work. Technological means to a better use of water can be viewed both at the delivery

system and at the field level. Both are important, but from a policy point of view, the latter is more crucial, and may be more responsive in preventing negative environmental impacts.

Irrigated agriculture, being characterised, in many locations, as a nonpoint source pollution phenomena, necessitates more attention in developing environmentally friendly irrigation technologies. Although some may claim that such technologies exist, they may need adaptation to local conditions, and assistance of extension in introducing them to irrigators.

Public and private funds should be invested to develop new water and crop technologies. Current public expenditures on agricultural research are typically less than 0.5 per cent of agricultural domestic product. Only 20 per cent of this meagre sum goes to water. As might be expected, the expenditures on research as a percentage of GDP are especially low in the low-income countries. Therefore, in the era of almost free information flow, public research can lead in the important task of introduction and adaptation of pollution-reduction irrigation technologies.

Additional investments are needed to develop engineering designs that allow timely and flexible delivery of water to farmers so they can meet crop-water requirements. Improved hydrological tools are needed for recharging groundwater aquifers and for controlling pollution. Modern technology is needed for recycling drainage and waste water and for watershed management. And, not least, new crop varieties must be found that produce greater yields with less water.

Incentives for conservation, better management, and adoption of technologies

While many policy makers still approach water policy issues from the supply-side point of view (investment in more diversion, more storage, not enough emphasis is put on incentives that signal the value of water and induce conservation and better management.

Although, new and unconventional water resources will need to be developed in the long-run, there is still room for better management that is driven by incentives and education, that will result in additional useable quantities of water that were made available of the original allocation. Water conservation efforts, leading to the use of water saving technologies and management practices are the key for water saving and reduction in environmental pollution. Price⁸ policies for water, water-use technologies, and pollution-related inputs should be encouraged by governments, especially in pollution sensitive regions.

Policy implementation

One of the drawbacks of past policies is the lack of sufficient and adequate monitoring and enforcement mechanisms. Water quality and environmental related problems are not merely a technical question. The more difficult questions are often political, institutional, and social. Since these components are interrelated, only by defining and addressing the system as a whole, can a sustainable policy be implemented. To ensure appropriate implementation of policies, certain water-related institutions are necessary. Policy makers and project managers should design monitoring systems and provide support for evaluation of monitoring data.

8. "Price" stands here also for taxes and subsidies.

Global concerns

The transboundary nature of water-related problems, quantity and quality alike, and the growing awareness of the global dimension of some water-related problems, have to be recognised in future policies. Principles agreed upon in international accords concerning use and pollution of international water, and growing concerns regarding global warming and accumulation of green house gases, that could increase global temperature and change climate patterns, should be part of domestic policies, and co-ordinated with regional activities.

Collaborative-co-operative arrangements

Some US\$600-800 billion of investments in water supply and sanitation and irrigation and hydro-power is needed during the next decade. Ninety per cent of this will have to come from the developing countries. Sixty to US\$80 billion will be provided by external support agencies. The World Bank can be expected to provide US\$30 to US\$40 billion to finance these investments provided governments are committed to an agenda of reform (Serageldin 1996).

Not only governments should be committed to reform. International lending and development institutions should also define future policies that allow the sustainable development of irrigated agriculture. For example, the World Bank is shifting its lending portfolio towards overall water resources development allocation and conservation. The focus will be on comprehensive water resources development and management and not on sub-sectors in isolation. This does not mean that the Bank's lending to irrigation will fall by the wayside. It does mean that the Bank will lend to irrigation only where water use for irrigation fits into a larger water resources strategy, where distortions are minimal, and where there is a commitment to stakeholder involvement in irrigation management.

The success of efforts by the Bank and its clients will depend crucially on the ability of countries and international institutions to work together in partnership in order to acknowledge needs, share knowledge and leverage resources.

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ECONOMICS OF WATER ALLOCATION AND THE FEASIBILITY OF WATER MARKETS IN AGRICULTURE

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1. Introduction

Most attendants to this seminar are aware of the stressful conditions under which many countries' water economies are evolving. As water resources become increasingly scarce, past policies which promoted water use through investments in water control facilities have become outdated. Water scarcity is not only a question of quantity but also a matter of quality; it encompasses as well temporal and geographical dimensions. Scarcity has both deterministic and random components, which need to be disentangled and, perhaps, tackled with different measures. Because available natural supply is insufficient to meet all agents' needs and wishes, new ways to allocate it need to be found. This task is challenged by multiple obstacles.

To begin with, current patterns of water uses are the result of higher hierarchy political objectives such as urban and land use planning, rural development and food security. Secondly, past water policies were based on assigning solid water rights to consumptive users, so that a sufficient guarantee of water supply could protect the investments required to put their allotments into productive use. Therefore the objective to redirect water use patterns hinges upon deeply rooted traditions, beliefs and customs. Thirdly, while water authorities in the past have enjoyed a significant degree of political autonomy, they are now much more constrained, and sometimes challenged, by other public and social institutions. As a result, the task to allocate scarce water among users and at the same time improve its quality and the ecosystems it sustains is formidable.

This paper's objective is to enquire about the role that decentralised systems can play in allocating scarce water resources among competing users. Special emphasis will be given to designing principles, performance, and legal implementation in order to make a critical assessment of a selection of examples. It also aims to draw useful conclusions, formulate policy recommendations based on the reviewed experiences, and provide a tentative outline of principles that should preside the liberalisation process water sectors. Although sometimes cumbersome, I consider it useful to cite the most relevant sources and recent literature.

2. Key concepts and definitions related to water markets

Types of water rights

Water markets are based on the definition of water rights. To be complete, a water right should specify the following details: volume of water to be withdrawn, duration of use, location of diversion and of the water returns, time of use, and type of use. Either one of two main doctrines has been followed to define *consumptive* water rights:

- *Appropriative* rights entitle holders to make “beneficial” use of certain volumes of water. Appropriative rights are divided in two categories:
 - *Priority rights* grant access to water following an order determined by the chronological order in which the rights were obtained, the earliest being the most senior. *Contingent* or *junior rights* entitle its holders to use water only once *senior* holders have fully used their allotments. By definition, priority rights are heterogeneous.
 - *Proportional or correlative rights* are homogeneous rights defined by a proportion of a watercourse flow or waterbed volume of water. These can also be *continuous*, *discontinuous*, or *alternate*.
- *Riparian* rights entitle right holders (usually located adjacent to the water body or flow which the holder may utilise (to make use of its water without altering in a significant manner the quantitative and qualitative properties of the water body or flow.

Water markets vs. markets for water rights

Market-based mechanisms can be set up on permissions to trade either temporary water rights or permanent water rights. With the former, water use rights are transferred among parties for a limited time period. Alternatively, if two parties exchange permanent water rights, the seller transfers to the buyer his complete water rights, relinquishing any option to reinstate his initial position.

Types of water markets

Although informal water exchanges have been reported in many countries, I will focus only on market arrangements that envisage some kind of legal or administrative provisions to guarantee minimum levels of rights enforcement. With that in mind, several types of markets can be identified:

- *Spot or lease-out markets*, in which the seller surrenders a given volume of water to the buyer, generally on a very short-term basis.
- *Water rights markets*, which involve transferring the property rights from seller to buyer for good.
- *Contingent or option markets*, in which the seller offers the buyer the option to make use of his water rights only when some commonly agreed event occurs. In return the buyer

will pay an option fee, no matter whether the right is exerted, and an execution price if water is eventually claimed during the specified period.

Water rights over water returns

Water returns refer to the fraction of the diverted volume of water which is not consumed by users and ends up returning to the watercourse. While it is difficult to conceive any water use which does not generate greater or lesser volumes of water returns, in many cases returns are difficult to control and evaluate. When water returns can be monitored at a reasonable cost, water legal systems may or may not issue rights over those volumes. Commonly, in watercourses that have been fully assigned to rights-holders, some of these — located in lower river tracts — might be using return flows even though their rights do not explicitly define property to water returns.

Definition and initial distribution of property rights

Water volumes and flows can only be measured up to a given level of precision. As a consequence, water rights are subject to the same level of uncertainty, and will never be perfectly defined. More precise definition of property rights generally implies higher market efficiency and lower transaction costs. When markets are created *ex novo* and implemented over a previously centralised system, some criteria have to guide the distribution of water rights before allowing its holders to initiate exchanges. Differing criteria may be used to distribute rights among senior users than to assign rights over newly created or unexploited sources of water supply.

Third-party effects

Any water exchange can potentially erode the benefits of agents whose interests are not represented by the parties involved. The concept of third-party effects encompasses also the case of returns, users being affected by a water sale, but clearly includes a much broader set of effects. Perhaps the most relevant case is such that occurs when non-consumptive users are injured by a water exchange that results in reduced inflows or in water quality degradation. Hereafter, the term “non-consumptive benefits” will be used to denote preservation of ecosystems, natural habitats, and biodiversity levels, as well as more “tangible” uses such as fishing, swimming or boating. In most legal arrangements, right-holders for consumptive uses are granted ample scope to file complaints against transfers that presumably injure their rights.

The spatial and sectoral dimensions of water markets

One key feature of any water exchange is the distance among the two parties relative to the size of the basin or water body whose waters will change hands, or whether both are in the same country and/or basin. Of equal importance is whether or not water rights can be transferred across parties of different sectors. Commonly, market rules have specific provisions on both questions.

Specific provisions for groundwater markets

Markets for groundwater can be developed using two alternative systems. One way is to assign tradable pumping rights to the users located on the surface encircled by an aquifer perimeter. These rights grant each holder permission to pump a proportion of the total aquifer extraction, which is determined by hydrogeologists with much or lesser precision. Alternatively, markets could be developed over water volumes pumped to ground level, but users would not be allowed to sell their pumping rights.

Price revealing mechanisms

Water exchanges take place in a wide range of forms and agreements. As before, I only give account of those that have been used in legal water markets:

- Water mining companies could allocate differently graded water volumes on daily or weekly *auctions*.
- Permanent water rights are usually traded following practices similar to those of real state markets. Price levels from direct or indirect *bargaining among parties*.
- Public water authorities may act as *clearing houses* either allowing sellers and buyers to find equilibrium prices, or unilaterally setting fixed prices for sellers and buyers.
- Buyers could agree on *financing sellers' water conserving technologies* and more efficient conveyance and storing facilities in return of volumes that without those investments would have been used by sellers.

Actual versus virtual water trade

Essentially, with *actual* water trade the seller forgoes the agreed volume of water making it available for the buyer. With *virtual* water trade, the exchange involves a transfer of water rights of third-party users, irrespective of being or not being consumptive users. Perhaps an example will help to clarify this arrangement. Assume consumptive users A and B have rights to water of different sub-basins that belong to the same basin, and that both have dams to control their tributaries' flows. Let's suppose that down the main river there is a trout fish-farmer with rights to use a part of the flow, and that that flow is to be met year-round from some basin's reservoirs, including A's and B's. The virtual trade would entail B serving the flow that would have been released from A's reservoir, thus allowing A to make use of those resources. Note, however, that this arrangement has potential third-party effects as well as likely alterations of the water returns regimes.

3. Assessing water markets' performance

Sources of welfare gains

Water markets are intended to facilitate voluntary water transfers to the benefit of both buyers and sellers. In essence and fulfilling several conditions, water transfers are always welfare improving due to the fact that buyers and sellers, acting voluntarily and furthering their own interests, become

better-off after trade. Besides generating direct private gains, that accrue strictly to parties, water markets are sources of social gains.

Firstly, markets help distribute scarcity signals even among those that have no intention to participate in them. This is especially important because in most real markets the traded volume of water represents but a small fraction of the volume available. As water is priced at market rates, users receive an unambiguous signal about the opportunity cost of water. The result is that users internalise, and act as if they were charged a price equal to, the true opportunity cost of water resources within the market boundary.

Secondly, water markets provide strong incentives to adopt new technologies, especially those that are water-conserving. It is worth noting that technology adoption *per se* is not synonymous to water conservation; in fact, in many instances, better irrigation technologies increase the amount of water that reaches the root zone relative to the volume of water that is conveyed to the water district and to the farm's door. This potential danger can be avoided if the water saved through more effective water use is not spread by its holder to other activities or more intensive use, but made available to potential buyers.

Thirdly, access to water markets can become an alternative to building more structural facilities (see Michelson and Young, 1993; Fisher *et al.*, 1995; Hamilton *et al.* 1989). In particular, optioning water rights is a promising alternative for municipalities to avoid the increasing cost of securing new sources of water which will be used infrequently. An option contract allows the buyer to obtain supply security from the seller, who in turn is drawn into option contracts because both the option price and the exercise price are sufficiently high to cover the expected losses of not using water in a number of periods (see Howitt, 1997 for further details).

Fourthly, water markets can be used by public authorities to obtain water resources from private holders in order to restore natural habitats and watercourses conditions. As private users differ from each other in the marginal benefit of the water they use, the state can get the water from those that place on it the least value. Hence, public goods can be provisioned at the least possible cost.

Fifthly, water markets can be a second-best policy to correct nonpoint pollution generated by intensive farming (see Weinberg *et al.* 1993; Weinberg and Wilen, 1997; Dinar and Letey, 1991). Because water consumption is linked to the use of chemical inputs which return to water bodies through draining, it is hypothesised that water markets can provide incentives to change water use technologies to reduce water drainage and/or reduce chemical use. While these and other studies show unambiguously the environmental benefits of water markets, this effect is not a primary motivation to establish them. In addition, too little is known on the effects of actual water markets on water pollution, and on whether or not pollution is ultimately reduced relative to the non-trade situation (see the Australian experience below).

Water markets and irrigated agriculture

Most water markets that operate or have been proposed across the world, call for one or another form of farmer participation. It is safe to contend that water markets could hardly exist in the absence of irrigation. Several reasons back this assertion:

- As water becomes more valued by non-agricultural users, its market price arises relative to the cost of transporting it from more remote locations.
- Global markets make access to food commodities much easier and cheaper than before, making agricultural production now less irreplaceable than one or two decades ago.
- In most regions where water markets are operating or being in the process of initiating, agriculture is by far the major water consumer. Since in most cases only a fraction of farmers' water rights are truly demanded for other purposes, water markets seem the most adequate procedure to transfer them.
- Most irrigated lands that use resources for which there are potential claimants were developed and issued water rights, evaluated for cropping patterns and technologies that are nowadays outdated. Substantial evidence seems to indicate that it is easy to save water from agriculture without inflicting major business damage to the sector.
- Most farmers within a small water circumscription are serviced by common water districts that use common facilities to store and retail water for its contractors. Hence intra-sectoral water markets can be easily established to allow farmers to exchange water among themselves, and inter-sectoral wholesale markets can be organised without much informational requirements nor further structural facilities.

Gains-from-trade to the agricultural sector

Water market experiences across the world show that exchanges among agricultural users are common. Generally, these exchanges arise because intensive farmers buy water from other farmers who fallow land or move from more to less water demanding crops. As a result, the land base of more valued crops will expand as that of less valued crops will recede, boosting the aggregate agricultural output and perhaps farm labour.

Water exchanges between agricultural and urban users in return of investments in capital improvements within the farmers' water districts are far from neutral. It is well documented that better technologies imply a better life for farmers and, perhaps more importantly, better quality products, especially if these are fruits and vegetables. Improvements in conveyance systems financed by water buyers might help as well to refine the control of water distribution within the districts, lowering in turn the administrative costs.

Analysts view water markets as a tentative strategy to safeguard the agricultural holders' interests against the inevitable trend in favour of urban/industrial and environmental uses. Their argument is based on a plausible, though not testable, assumption: since water will eventually need to be reallocated to serve urban and industrial users and to enhance instream values, markets allow farmers to sell their rights dear and, if sensibly regulated, insure that the transition process takes place gradually and peacefully.

Losses and disadvantages of water markets to the agricultural sector

Real water market experiences show that ill-designed market rules or excessively liberal environments are sources of potential conflicts:

- With inter-sectoral water markets, farmers might end up selling their water to urban/industrial users, harming the economy base of rural communities. Some authors have even pointed out that water markets eventually lead to cultural and economic degradation in rural areas. These criticisms are well made and strongly backed by empirical evidence.
- Water markets can be strongly contested by farmers, based on cultural as well as strategic motivations.
- Water markets can have potential equity impacts if large water buyers exert their power to obtain water resources from a large number of small land and water rights holders. Poor training in legal procedures of small landholders give powerful market participants too much scope to impose unequitable terms of trade.
- In the presence of saline water and soils, trade among farmers can induce water greater in areas where it would be better to reduce water use.
- In spite of implementing successful programs to reduce total extraction, markets for pumping rights can depress aquifers' potentiometric cones.
- Water sales out of the agricultural sector can add stress on delivery and drainage systems, and can reduce the value of land used as loan collateral.
- Water markets can induce changes in cropping patterns that might enter in conflict with agricultural policies, such surface references established by the European Community Common Agricultural Policy.

4. Differential approaches to water markets: potentials and disadvantages

This section attempts to critically evaluate the most relevant world experiences, paying special attention to identify major sources of conflict or synergy within the agricultural sector.

The Chilean approach

Market organisation and water rights in Chile

Chile's 1981 Water Code brought its water economy to a previously unknown degree of liberalisation. Some of its key components are the following: (1) it ensures the security of water rights, and allows holders to transfer, rent, lease and mortgage them; (2) water rights are legally defined as volumes per unit of time, though practically as proportions of flows or as reservoir shares; (3) rights-holders, who are granted rights free of charges, may or may not make use of their rights; (4) since water rights are considered as real state property, conflicts are solved in civil courts, whose sentences can be appealed on Appellate Courts; (5) the public water administration, General Water Directorate (GWD), grants requests free of charge (if there remains enough water that has not been appropriated), auctions rights if all requests can not be satisfied, and takes on responsibilities dealing with technical works and planning major facilities; (6) transfers are only subject to GWD's authorisation when trade involves a change of the abstraction point from a natural flow; (7) users of water returns are not granted water rights and cannot file legal demands to obtain compensations for

any change of water returns regimes due to water exchanges; and (8) non-consumptive rights have also been granted to hydroelectric companies.

Market performance in Chile

Since 1981 water markets have permitted some degree of water reallocation between irrigators and from farmers to urban utilities, albeit only in two or three river basins. In general, farmers have opted to hold on tight to their rights, presumably incurring in the opportunity cost of keeping water rights that are rarely used. A number of reasons have been identified to explain both the fact that too few transactions have occurred in most basins and the failure of prices to convey more efficiency, information about water's true value: (1) lack or inadequacy of structural facilities to permit transfer waters from sellers to buyers; (2) high transaction costs (see below); (3) an initial distribution of water rights that more or less resembled market equilibrium outcomes; (4) the fact that legal property titles to water are dispersed in three different public offices; and (5) the permission to hoard water rights at no cost for limitless periods.

Critical assessments

Analysts disagree on how to judge the results of the Chilean experience. The most critical views are those held by Bauer (1993, 1997a and 1997b), Vergara Blanco (1997) and Rubalcaba (1997). More favourable evaluations have been done by Hearne and Easter (1995), Rosegrant and Binswanger (1994), Thobani (1994), and Gazmurri and Rosegrant (1994). On balance, the most important lessons to be drawn from the Chilean experience are the following:

- Water titles should be registered, as well as updated, in one single institution.
- When both non-consumptive and consumptive users hold rights for the same watercourse, clear provisions need to be made to avoid fractions caused by conflicting timing on dam release and flow controlling operations.
- Hoarding of water rights allowed one single power company to hold 58 per cent of the nation's water rights at no cost, of which only 13 per cent was being used. (Rubalcaba, 1997).
- River fragmentation in almost independently managing sections seriously impedes advances of sustainable basin plans and water quality improvements.
- Since the same watercourse is held by various non-consumptive users, these have outnumbered consumptive holders in river sections vigilance committees, which have been reported of taking decisions in favour of hydropower utilities.
- The water state authority (GWD) has been deprived of some important tasks to regulate river basins in favour of civil and appeal courts, and seems legally impeded to pursue public good benefits without eroding or altering existing water rights. Any action to amend unquestionable mistakes is successfully challenged by those right holders whose privileges might be encumbered.

The experience of the Californian water banks

Banking schemes have been recognised as feasible alternatives for users seeking to gain water supply security without purchasing permanent rights that would only be used occasionally and would dry up agricultural land unnecessarily. These well-documented experiences have inspired dozens of articles, books and documents, which to a great extent coincide on granting the experiences very positive outcomes. Interesting works have been done by Israel and Lund (1995), Carter *et al.* (1994), Miller (1996), Howitt (1997) and miscellaneous documents done or commissioned by the California State Department of Water Resources (DWR).

Motivation

The California Water Bank (CWB) was developed in 1991 to ease the impacts of the four-year drought that had brought the State's water reserves to levels unable to meet water needs of important urban and agricultural areas as well as of natural wildlife habitats in the Southern part of the State. Legislative and technical studies initiated upon the 1977 previous drought facilitated in a significant manner the establishment of the 1991 CWB. The objective was to induce water rights-holders in regions with available resources to contract with the DWR to give up using all or part of their water rights, in order to make available, a related amount of water to buyers located in different regions. These in turn were required to provide documentary evidence on the maximum use of their reserves, set forth conservation strategies, and show ability to fund purchases.

Solving important constraints

Several of the most critical issues demanding especial care are the following:

- Since the transfer scheme was going to change the pattern of inflows of the San Joaquin and Sacramento rivers to the San Francisco delta, special care was needed to respect the delicate delta's hydrological balance.
- To make sure that the delta's constraints were respected, the CWB anticipated that it would make available to buyers only 70 per cent of the water made available by sellers. Since sellers would be compensated by 10 U.S. cents per cubic meter and buyers would pay 14 U.S. cents, the price margin was used to acquire the additional volumes of water needed for that purpose, as well as to cover the operating costs.
- Sellers were legally authorised to sign contracts with the CWB without risking later water rights forfeiture or loss. This served to encourage potential sellers, particularly those with rights issued by public institutions, to sell their water without fearing that their conduct could be later on used to argue that they had not put it into "beneficial use". Despite this provision, Howitt (in Carter *et al.*, 1994) shows that holders of water rights served by publicly developed projects were much less willing to enter in bank contracts than those that held fully private water rights.
- The DWR allocated water to potential buyers following a specified set of priorities, on top of which were emergency needs, such as health and safety.

- To avoid the need to measure actual volumes of water, sellers needed to contract acreage that would be left fallow and to provide evidence about the cropping patterns they would have scheduled had they made use of the water instead of contracting it with the water bank. For each type of crop, a gross measure of water consumption was used to pay farmers for the land left idle.

Market participants and performance

Whereas about 80 per cent of the water bank was purchased by urban and industrial users, 50 per cent and 32 per cent of the water was obtained, respectively, from farmers fallowing land and through ground water substitution contracts. Howitt *et al.* (1992) evaluated in \$32 million the 1991 bank's net benefits for the agricultural sector (out of \$91 million total gains-from-trade). Technical studies were commissioned to check that ground water substitution contracts did not lead to river flow reductions, and that the sold volumes were not made up by groundwater pumped from aquifers linked to surface watercourses. Despite the overall good evaluations of the CWB, analysts have identified several shortcomings, some of which were corrected in the much smaller 1992 and 1994 water banks, which are worth reviewing:

- The fact that both sellers and buyers prices were set at the beginning of the season created an excess of supply of about 32 per cent, which of course could be stored, but nonetheless seems exaggerated. An option scheme was implemented in the 1992-94 Banks, so that only the water that was effectively demanded could be finally purchased. Those that put option water available to the banks before a certain date were paid a reservation fee, irrespective of whether or not water was purchased. If finally purchased, they would be given the regular water purchase price.
- Water sellers were scarcely dispersed in the selling regions, intensifying the negative effects to the local economies where most contractors were located.
- Representatives of the affected businesses complained that they had not been informed with enough time to anticipate their businesses' shortfalls.
- Environmental constraints have been tightened by the Central Valley Water Improvement Act (1992), imposing more demanding constraints that will have to be overcome in new banking arrangements (Gardner and Warner, 1994).

Lessons to be drawn from the Californian water bank

In emergency situations, price signals need not be excessively refined to reallocate water resources among competing users. Water banks run by public agencies are ideal systems to reduce transaction costs of occasional wholesale water transfers, and facilitate reallocation in relatively short time periods. The joint contribution of two important factors largely explains the success of the CWB. One is the complete control by the State agency of the whole process to reduce legal and environmental risks associated with the massive water transfers. The other is the fact that water sellers became so, as a result of a voluntary decision, totally backed and supported by the legislation enacted on purpose. It is worth mentioning the fact that the CWB could only be emulated in places or countries with a very efficient and socially respected water administration, and counting on an extremely developed scientific base on all aspects linked to the water sector.

The Australian approach

Australia's water industry has been, and still is, heavily controlled by the public state and federal water authorities. About 15 years ago, Australian water public institutions initiated a reform to change its institutions and water policies, including, among others, implementing full cost-recovery prices, halting further diversions, enhancing inflows to restore the ecological quality of rivers, and allowing users to trade over water rights to increase the flexibility of water allocation. Whereas some of these are yet to be implemented, tradability of water rights is already a common practice among agricultural users, and less common across sectors. In my opinion, the Australian example provides interesting lessons for countries that are in the process of pursuing water reforms that incorporate market-based mechanisms. The attention is justified because Australia's water reform is proceeding slowly, cautiously, and intensively restrained by other objectives different from the promotion of the economic efficiency. Good sources to learn about the Australian Experience are Pigram *et al.* (1992), Musgrave (1996), and Pigram and Hooper (1990), as well as the reports prepared for this Workshop by Greig (1997) and by Aeukens *et al.* (1997).

The basic details of Australia's approach to water markets

Although each state is following a slightly different approach, several common features are worth reviewing. Firstly, while water rights-holders are allowed to transfer their rights subject to several constraints, the Australian states have retained substantial power to modify the components that define any transferable water entitlement. Secondly, states have (1) imposed severe restrictions to transfer entitlements across sectors and large distances; (2) proceeded allowing initial transfer permissions for one single year, though lately some states have allowed five-year transfers; (3) followed a hands-off policy to allow parties to decide about the terms of trade; (4) kept power to halt transfers based on proven third-party effects or on evidence that the transfer might affect channel and drainage technical capacities; and (5) imposed volumetric reductions schemes of traded water rights, based on the location and types of both parties, and established market access fees. Thirdly, the process of implementing market-based systems has been coupled with provisions to allocate water rights to enhance instream uses and water quality, to enact a water price reform, and to guarantee permanent contacts with users and stakeholders to monitor and redirect water policy reforms. Fourthly, in some states graded water rights, based on different security levels, were issued to allow users to gather a matching combination of rights with their possibilities to accommodate random supply cuts.

Australian's experience performance

Since 1983, when entitlements transferability was initiated in South Australia and New South Wales, water markets have not originated large volumes of water trade. Evaluations done by Pigram *et al.* (1992) show that welfare gains are, at least from a short-run perspective, quite limited. Most of the water exchanges have been limited to the agricultural sector, allowing high-value crop producers to expand their land base using water from other irrigators' entitlements which previously was devoted to low-value crops, such as fodder and alfalfa. Most sources seem to coincide in raising the following diagnostic points:

- Transferability of water rights have in many cases and locations expanded water use and reduced supply reliability because it gave incentives to holders of "sleeper" rights to put

them out for sale to buyers who did make use of the water. This problem was particularly critical in the Northern Adelaide Plains, the only case of water markets with groundwater resources.

- Groundwater markets have proved difficult to reconcile with the objective of the sustainable management of aquifer levels. Specific zoning provisions were needed to mitigate the worsening of potentiometric contours caused by the exchange of pumping rights used in different aquifer dominated locations.
- As the states retained power to alter the nature of the temporary water rights, the entitlements were perceived as not completely secure property rights, adding substantial uncertainty about what exactly was being traded. In return, Australian authorities have been able to back up and change market rules when problems became evident.
- Concern about two additional indirect effects was also raised:
 - *Pecuniary externalities*: both as a result of a reduction of the local tax base due to regions surrendering permanently to buyers some of their entitlements, and the fact that the fixed costs of the irrigation infrastructure might need to be borne by fewer rights-holders. Most states charged transfer fees to account for these problems.
 - *Reduction of real state values*: a potential impact which was raised by financial institutions with outstanding loans which had irrigated land as collateral. Some states require written permission from lending agencies with financial interest in an irrigation firm that is interested in exchanging water rights. Permanent transfers are, naturally, the ones that draw most of the attention from financial institutions.
- From the very beginning, small landholders have been concerned about the potential distribution effects of water markets. As increasingly larger market trials were being implemented, these adverse effects were hardly present. Hence, initial fears of small farmers becoming worse-off were soon eliminated.
- Salinity problems in the River Murray, previously thought to be mitigated by water transfers, were initially exacerbated because of two reasons:
 - *Imperfect correlation between water applications and discharge of water*.
 - *Activation of “sleeper” rights* caused by market incentives, which increase water use in sensitive sections of the basin.

Lessons to be drawn from the Australian experience

Caution, acceptability, cost-effectiveness and sustainability are perhaps the four guiding principles to reform the Australian water industry. The cost is clearly borne in substantially fewer transfers than would have occurred in a much more unfettered environment. However, since 1994, the Council of Australian Governments (COAG) has encouraged water trading in response to problems encountered between States over the management of water. States in turn have enacted new laws and approved further provisions to follow COAG’s recommendations to promote efficient water use through water

trading. Two other important principles seem to be guiding the Australian process of reform. One is the fact that transferability of entitlements is one component within a major policy reform, which perhaps reflects a truism, namely, that markets left alone could worsen already stressful situations. The other is the readiness to take significant backward actions, thus avoiding the danger of perpetuating damages caused by badly designed market rules or by factors that had been initially overlooked.

The western United States approach(es)

A hundred-year history of water trading can hardly be told in one single page. Not least because we would need to review not one but many experiences and approaches. One additional difficulty is that market-based systems have been the only institutional setting which, despite having been profusely modified and regulated, has guided water allocation in most Western States. Hence, unlike the analysis of Chile, Canada, Australia, Israel or Spain, we ignore what would have happened if the Western States water economies had evolved differently. The literature is extremely large; thus, I will just mention some of the most cited or recent: Saliba and Bush (1987), Young (1986), Howe (1997), Howe *et al.* (1986), Griffin (1997), Maass and Anderson (1978), Colby (1997), and Vaux (1986).

The doctrine of prior appropriation

Most water sources of the Western states are used by agents holding priority rights. Unlike proportional rights, priority rights allow holders to claim water in an orderly fashion in which seniority is based on the recorded date when water was first put to “beneficial use”. Any holder who does not use his irrigation water for a number of years risks losing it (see *The Economist*, 1997; to learn about water fights in Wyoming). Although riparian rights, as defined by English Common Law, were in force until the beginning of the 20th century, in all Western states, except in California — where riparian rights are still enforced — the prior appropriation doctrine gained increasing prevalence as natural water supplies became fully appropriated. Water markets have existed in New Mexico, Wyoming, Colorado, Utah, Arizona, and California for more than a hundred years. Although river basins cross border-states, market provisions are state specific and differ among each other in important aspects. Basic common features are: the recognition of return flows user rights, a more or less broad definition of “beneficial use”, the existence of various institutional arrangements to solve conflicts, and certain limitations to transfer water out of the region and/or across sectors. Uncommon features are, among others, water rights appurtenant to land property (Wyom. and Ariz.), new developments of proportional rights sharing waterbodies (Col.), and the absence of an Office of State Engineer, whose function is performed by division water courts, to provide initial clearance for filed water transfers (Col.).

US western states’ experience performance

On most grounds, water markets have played a significant role in reallocating water to competing users in parallel with the evolution of the State economies and social values. Analysts coincide in granting positive assessments to water markets. Water market prices vary substantially with time and location, with other factors such as rights’ seniority, volume of water being transferred, and the type of market participants being also explanatory factors of price variation. While in the last decade most

exchanges have transferred water out of the agricultural sector, substantial trade among farmers have also been, and still are, very common. Some identified sources of problems are the following:

- Out-of-agriculture transfers have inflicted devastating damage in some rural communities' tax base and income. The existence of backward and forward linkages with other businesses proves that water sales have had important effects on rural areas (see Howe *et al.*, 1990).
- Water quality and quantity issues are looked after by separated institutions. Quality problems and the protection of ecosystems and natural habitats began to gain attention when Federal regulations such as Clear Water Act, Endanger Species Act, and the National Environmental Protection Act were enacted.
- Native American water rights have started to be recognised very recently. Before, American Tribes had been deprived of ancient water access, causing decline in many communities. Now this trend has began to be reversed (Colby, 1997).
- High transaction costs are perceived and interpreted differently among experts. Colby (1993 and 1997) contends that environmental groups can use the threat to initiate litigation to halt or obstruct water transfers on the grounds that it might infringe the previously cited acts. This interpretation is flawed in the sense that only rights-holders are generally allowed to file protests, leaving non-consumptive users more handicapped to file protests.
- Howe (1997) relates high transaction costs with unequitable market effects due to the fact that small holders are unable to incur in large lawyers', attorneys' and engineers' fees to challenge presumable injuring water transfers. Cities and large participants can much more easily incur the litigation costs to obtain approval of, or halt, transfers.

Lessons to be drawn from the western U.S. experiences

Having in mind that water law in western U.S. is well established, and profoundly rooted in its historical development, some initiatives promoted by single states or water projects provide some lessons worth mentioning.

- An independent public office of engineers and hydrologists is perhaps the best institution to initially accept or reject filed petitions for water transfers. Its decisions are equitable, independent, and well rooted in scientific knowledge. Of course, litigation in state courts to challenge its decisions is still possible.
- Instream property rights need to be recognised through the definition of broader concepts of "beneficial use". Public goods should be defended by state agencies, either participating in markets or granting access to NGO to acquire rights for environmental purposes. These options began in the late 1980s, although they were pursued through legal procedures which are yet to be fully developed (Colby, 1997).
- Lease-out contracts should be promoted when water scarcity results from below average run-off.

- Buyers of permanent rights to be used out of the region should be required to provide payments to fund compensation schemes to communities and affected businesses. Thus, water acquisition prices would better reflect social values, on top of sellers' reservation price.

The experience of the Canary Islands (Spain)

Since the nineteenth century, the water industry in the Islands has been to a large extent in the hands of the private sector, and completely detached from land property. The Canary Islands' volcanic and abrupt nature makes it extraordinary difficult to obtain, store and transport water. Water's overwhelming scarcity, combined with intensive agriculture and increasing reliance on tourist proceeds, has encouraged costly efforts to capture fresh and deep ground waters, resulting in the complete exhaustion of natural springs.

At present, the principal source of water supply for the Island come from mining its over-exploited aquifers and from desalinisation plants. Private entrepreneurs and joint ventures have drilled hundreds of galleries into the mountains to capture water, which once brought to surface, are sold through intermediaries to private water carriers, and finally conveyed to municipal or agricultural users. The shares of water mining firms do not differ from other capital assets, and have attracted savings of more than thousands of households, most of them unrelated to the water sector. Water conveyance and distribution capital is extremely refined, which should not be surprising when water fetch prices well over 50-60 U.S. cents/m³. Some sources to look at for the Canary Islands are Domínguez Vila (1996), Bautista Medina (1996), and Aguilera Klink (1993). Further details are the following:

- There is evidence that the rule of capture has brought the aquifers to sub-optimal productivity levels. Water mining has been subject to a totally unfettered laissez-faire policy, rendering the aquifers conditions subject to the decisions of a large number of uncoordinated agents, including municipalities and other public institutions that are market participants on equal grounds as private users. A Law passed in 1990 will impose more rigid conditions on hydrological constraints and on water owners' rights and duties, giving also more prominent roles to the newly created water public institutions. It will follow the Spanish constitutional mandate to return water sources and bodies to the public trust, and to convert mining firms into holders of pumping rights conceded by the Islands' water authorities. This will happen to its complete extent once the 75-year moratorium is finished.
- Water is used and conveyed very effectively. Fresh water's opportunity cost is very high and subject to expectations on further tourist development, size of the snow-pack, market perspectives for banana, tomatoes and other subtropical orchard productions. Although scarce, no significant water supply cuts have ever been reported.
- Environmental considerations are totally dismissed, and some coastal aquifers have been spoiled by excessive extraction. Private carriers have failed to grade water, mixing up pure with lower quality flows, perhaps thriving in confusion (Dominguez Vila, 1996). Unsurprisingly, the Islands' inhabitants are thought to be the worlds largest consumers

of bottled water, despite the fact that pure water sources originating from snow-pack are available.

- All market changes that experts would recommend to implement, aim at achieving a much more transparent market, disclosing much more information about market operations, and reducing the monopolistic behaviour identified, to no surprise, mostly in firms offering water transportation services.

Proposals to implement market options: Canada and Spain

This last section aims to present seminar attendants with the most critical aspects of the Canadian and Spanish water reforms, approved or in the process of being drafted, that incorporate market mechanisms. Water reforms are also in process of being developed in Peru, Mexico, India, and Pakistan, and the reader is referred to the World Bank Web page (<http://www.worldbank.org/>) to gather updated information on these and other countries' reforms.

Province of Alberta (Canada)

Horbulyk and Lo (1997) is a good source to learn about the project to introduce market-based systems in Alberta. The 1996 Water Act is a comprehensive proposal to reform the province's water industry, in which tradable rights is one of several other components. Although technical provisions have not yet taken effect, and will not come into force until 1997, some of its most significant guidelines provide some insight into reforming options:

- The conversion of historical rights into tradable property detached from land entitlements.
- Establishment of regional water management plans which, among other objectives, will determine how much water should be retained to enhance inflow benefits.
- Marketing options will be restricted across major river basins, and across the U.S.-Canada border.
- It will clarify licensing and approval process of water rights.
- The government will make use of a holdback provision to keep up to 10 per cent of the traded volumes to make them available to alternative public or private users.

Spanish proposal to reform the 1985 Water Law

These comments pertain to the reform's draft as of 15 May 1997. Recent publications on the Spanish water sector are Garrido (1997), Naredo (1997), and Sumpsi *et al.* (1996). In essence, the 1985 Water Law — which abolished the 1879 Water Law and is not in force in the Canary Islands — served to restore to the public domain all waterbodies, glaciers, watercourses, aquifers, and riparian lands. Agents were converted into temporary rights-holders, and impeded to change their

water rights characteristics up to the point of banning reallocating water use across land plots that belong to the same holder.

Such rigidity resulted in three effects not only positive but extremely useful for the purpose of reform. Firstly, the public sector has kept a solid grip on water resources, and on how they are used, allocated and managed; hence water reform can be set in motion at the desired pace. Secondly, Spanish basin agencies are the public institutions commended to put into force all Water Law provisions related to water planning, granting and enforcing rights, implementing quality standards, keeping rights registered, raising charges and effluent fees, and so on. Therefore, market mechanisms will be controlled and supervised by a basin level institution armed with legal power, at least in theory, to avoid many of the potential damages inherent to market mechanisms. Thirdly, the remarkable rigidity of the water rights systems has given rise to an extensive panoply of ingenious and sophisticated systems to confront supply variation over time, which will ease market transfers.

While in the past these and other facts have had probably large efficiency costs, they are now sunk costs that set the Spanish government in an enviable condition to initiate reform incorporating market systems in a gradual and cautious manner. As of 15 May 1997, the key details of the proposal are the following:

- Users will be forced to install and maintain metering devices.
- Under certain conditions, and subject to agency approval of the basins, rights-holders could lease their water to users of equal or higher seniority.
- Water-use rights will keep their legal status, but holders will be allowed to lease them or relinquish them temporarily to a publicly run water bank.
- The basin agencies will dictate specific provisions to avoid third-party effects and water quality degradation.
- The parties will be allowed to agree on the terms of transfer, which will have to be detailed in the contract to be filed in the agency register.
- If the transfer involves irrigators, the contract will specify the land plots which will be dry-cropped or fallowed, and those to be irrigated.
- The basin agencies keep, in all cases, the option right to buy the use-rights put for sale during a limited period of time.
- The government could issue decrees to develop emergency water banks to be run by the basin agencies.

5. Policy recommendations

This section attempts to summarise the most important lessons that can be drawn from the experiences and principles outlined above. I wish to make clear that, taken as a whole, my comments might not completely apply to any country's water sector. Each country has a record of water policies and historical constraints, a legacy of good and faulty efforts, and a relatively changeable and specific hydrological environment. Hence, market-based mechanisms need to be tailored to each one of these

conditions to allow them to play its positive roles to the greatest extent and causing the least costs. Yet it would certainly be presumptuous to give advice on water markets to water politicians in Chile, Australia or the U.S.. Instead, my objective in Tables 1 and 2 is (learning from theirs and others' experiences), to help water politicians in countries where markets are being designed to identify potential problems related to water markets, suggest mitigating mechanisms and bring out some of their secondary effects. I first enumerate some tips that may be useful to initiate water reform with market-based systems; next, I review some potential problems that pertain to water markets in general; and, lastly, I concentrate on specific problems related to the agricultural sector.

Strategic tips to implant market-based mechanisms

- Gather sufficient support from stakeholders and pre-market rights-holders. Reform should be perceived as a positive-sum game, in which winners will compensate indirect losers, who in case of being made worse-off will be given sufficient time to adapt.
- Anticipate and identify fears from irrigators and environmental groups; show them that the reform will protect and enhance their respective interests.
- Build and promote a deep scientific base on hydrological, ecological, sociological, legal, and economic matters. Predictability is based on knowledge and systematic thinking.
- Proceed slowly and cautiously. Pursue progress from thin to larger markets, from local areas to larger intra-basin regions, and from more to less fettered market rules. Promote monitoring reports, discussions, hearings, and constant up-to-date documents. Begin, perhaps, in voluntary water districts and/or basin tracts to trial market systems.
- Do not grant full and permanent tenured tradable permits until sufficient confidence is built about the system's well-functioning. We know this compromises short-term efficiency gains and hinders exchange, but avoids certain almost irreversible threats.
- Keep, reinforce or restore the public domain of water resources and the land base on which they flow and accumulate. Otherwise, the objectives of protecting non-consumptive water values and of facilitating transfers among holders would likely work in opposite directions.
- Embed market-based systems within a water policy reform, which should also include provisions for promotion of public goods, pricing policies, water management plans — for complete river basins, if possible — legal reform, and institutional change.
- Too few initial transactions should not be a primary source of concern. It is easier to promote them with slight provisions than to back up limiting the scope of already established rights' definition.

Table 1. Market difficulties, solutions and secondary effects

PROBLEM /DIFFICULTY	IDENTIFIED IN/ POTENTIALLY PRESENT IN	MITIGATING STRATEGIES	SECONDARY EFFECTS		COMMENTS
			NEGATIVE	POSITIVE	
Hostility from: - Farmers - Environmental groups	Australia, Chile, Canada, Spain	1. Secure holders' water rights 2. Use a percentage of the traded volume for inflow enhancement	1. Induces hoarding of unused rights. 2. Taxes trade	1. Investments' protection 2. Enhances inflows	Watch for strategic behaviour.
Incomplete or poor definition of rights	Mostly everywhere	3. Use proxies of water use (cropping and land-use patterns) 4. Invest in infrastructure	3. Imprecise measure of water use 4. Taxes trade	3. Reduces transaction costs 4. Facilitates trade	A gradual issue. Public agencies can provide assistance.
Market externalities and third party effects	Everywhere	5. Require public agencies' approval 6. Limit market circumscription 7. Open litigation to non-holders 8. Use a percentage of the traded volume for inflow enhancement	5. Technically demanding 6. Hinders efficiency 7. Promotes litigation 8. Taxes trade	5. Records transfers 6. Reduces pecuniary effects 7. Closer market scrutiny 8. Enhances inflows	Market externalities are one of the major concerns. If necessary, compromise market efficiency to avoid/limit them. Use predictive models to identify and quantify causes and effects.
"Sleepers" or pre-market inactive water rights	Australia, Spain?	9. Detract a percentage of the traded volume to avoid increases in consumption 10. Ban market access to holders w/o historical use records	9. Market efficiency 10. Unequitable, and requires a thin definition of "beneficial use"	9. Reduces opportunistic behaviour 10. Protects tax-payers' interests	A major concern in Australia, with surf and ground waters. Tricky question, but very important to anticipate and tackle.
Groundwater market externalities	Australia, Canary Islands, Spain, Texas	11. Zoning of aquifers' dominant area 12. Quantitative pumping records 13. Check whether groundwater contracts affect surface sources	11. Fewer transactions 12. Administratively demanding 13. Technically demanding	11. Sustainability 12. Better aquifer control 13. Favours conjunctive use of surface-ground water	Too few experiences: Canary Islands rather mixed; Australia not too good; Texas not too good.
Speculation. Hoarding of unused water rights	Chile, Canary Islands	14. Tax unused entitlements 15. Limit number of years of unused holdings	14. Hinders hydropower long-run investments 15. Unsecured rights	14. Equity 15. Market fairness, reduces market symmetry	Critical in Chile because inflow rights are solidly secured. In addition, the Chilean Water Code favoured power generation.

Table 1. (Continued)

PROBLEM /DIFFICULTY	IDENTIFIED IN /POTENTIALLY PRESENT IN	MITIGATING STRATEGIES	SECONDARY EFFECTS		COMMENTS
			NEGATIVE	POSITIVE	
Changes in the pattern of return flows	Everywhere	16. Issue 2 nd class rights to returns' users 17. Ban/tax down to upstream trade 18. Reduce market circumscription	16. Increases transaction and tracking costs 17. Fewer transactions 18. Lower efficiency	16. Protects investments of returns users 17. Protects inflows 18. Easier to control	Extremely critical and difficult issue. In general, markets should not generate important returns changes. It's an open question.
Transaction costs	Western US, Chile	19. Have public offices to decide on initial market approval/rejection 20. Keep updated, single basin-wise rights registries. 21. Decouple compensation from approval 22. Public agencies acting as clearinghouses or running markets	19. None 20. Hard for previously non-updated registries 21. Complicated balance 22. Costly and administratively demanding	19. Market efficiency 20. Forever useful 21. Market efficiency 22. Avoids many problems	A gradual question. Recently created markets can be run by public offices, which in time could become independent water "stocks". Transaction costs can also operate as environmental taxes that hinder undesired transfers.
Pecuniary effects. Economic damage on water selling areas	Western US, Canada, Spain, Australia	23. Set market fees to fund compensations 24. Limit to a percentage of tradable rights 25. Non-fallow land provisions 26. Disperse water selling units	23. Market efficiency 24. Market efficiency 25. Counter-productive 26. Difficult to rule	23. Reduces hostility 24. Reduces externalities 25. Dubious 26. Spreads damage	Time to adapt and money are necessary to avoid temporarily economic damage. Buyers should provide the required funds.
Asymmetric market power	Western U.S. and Chile	27. Aid small holders with free legal protection. 28. Make sure small ones are informed 29. Agencies fixing terms of trade 30. Monopoly regulation in presence of economies of scale	27. None 28. None 29. Market refinement/loss of market precision 30. None	27. Reduces hostility 28. Reduces hostility 29. Reduces transaction costs 30. Efficiency/equity	Most cases of asymmetric market power occur in litigation processes, in which small holders can't compete with large ones. In the Canary Islands, market power has been found in some water services.
Conflicts between non-consumptive and consumptive users	Chile, US, and potentially elsewhere	31. Broader definition of "beneficial use" 32. Set minimum ecological flows 33. Give priority to consumptive users over hydropower utilities	31. Legally tricky 32. None 33. Erodes power companies benefits	31. Enables environmental groups to buy instream rights 32. Enhances inflows 33. Equity; favours agricultural sectors	A real challenge for water markets. The major concern in Chile, caused by utilities outnumbering consumptive users in vigilance committees.

Table 2. Specifics of difficulties of water markets to the agricultural sector

PROBLEM /DIFFICULTY	IDENTIFIED IN /POTENTIALLY PRESENT IN	MITIGATING STRATEGIES	SECONDARY EFFECTS		COMMENTS
			NEGATIVE	POSITIVE	
Rural communities decline	Everywhere	See “Pecuniary effects” above			The challenge is to strike a balance between the adaptation to social changes and the protection of rural communities. Lease-out contracts are alternative strategies.
Over-appropriation of proportional rights to protect permanent or high-valued crops	Chile, Australia	1. Define two types of rights, one senior to the other. 2. Regulate and promote lease-out contracts	1. Market complexity 2. None	1. More efficient investment patterns 2. Higher water-use efficiency	Water districts could promote incentive-compatible allocative rules to ration water, based on members’ cropping patterns.
Salinity and other water quality issues	Australia, USA, Spain	3. Limit trade, creating zoning areas 4. Revise downward water rights 5. Charge market fees to cover drainage systems’ costs 6. Tax water use	3. Fewer transfers 4. Market efficiency 5. Market efficiency 6. Two policies hinging upon a common problem	3. Reduce externalities 4. Enhance inflows 5. Better draining control 6. Reduce salinity in the absence of trade	Besides limiting market transfers, and taxing water use, hardly any other arrangement is at the moment ready to be implemented.
Higher fixed costs of water facilities to be borne by fewer users	Australia, Spain	7. Force buyers to cover the payments corresponding to sellers’ liabilities 8. Charge market fees to cover costs	7. Market efficiency 8. Market efficiency	7. Gain farmers approval 8. Gain farmers approval	An easy problem to solve, that if neglected, could become a real problem.
Falling real estate values	Australia	9. Require written permission from lending agencies to clear market access 10. Allow banks veto perm. rights’ sales.	9. Increase transaction costs 10. Same	9. Property rights protection 10. Avoids market distrust	An easy problem to solve that, if neglected, could become a real problem.

Identification of problems and mitigating strategies

Water market complexity results from the abundant problems and difficulties that can arise because of poorly designed market mechanisms. At times, even well-balanced market rules can lead to unexpected and negative outcomes, simply because some factors that had been neglected or overlooked became critical once market operations were initiated. Yet the task to design market rules that mitigate negative effects is challenged by the fact that mostly all mitigating mechanisms have secondary effects.

Most of the difficulties encountered in the experiences reviewed above, have been included in Table 1, which includes general problems, and Table 2, which contains issues pertaining to the irrigation sector. Various mitigating strategies are suggested for each item and accompanied with some of their negative and positive secondary effects.

6. Concluding remarks

In view of experiences and ideas outlined above, it is beyond doubt that market-based mechanisms are not complete substitutes to the public administration of water resources. Inefficient public agencies, or the lack of significant public tasks, renders any water economy severely impaired to meet its water demand in a sustainable manner. This applies to liberal as well as centralised water sectors.

Once public goods associated to water resources are properly protected, market systems can play an effective role to reallocate water resources among competing private and collective users. Tensions between environmental and urban with agricultural uses can be harnessed to reasonable levels securing the agricultural water rights and giving its holders opportunities to lease-out or sell some of their resources to other users. Provided that these arrangements are subject to close control and that the buyers pay the full resource costs, market systems open avenues to set private incentives in motion to achieve not only higher economic efficiency but more practical ways to attain social objectives as well.

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INDICATORS TO MEASURE THE IMPACT OF AGRICULTURE ON WATER USE: PRICING AND COST OF WATER SERVICES

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1. Evolution of irrigation and its impact on the environment

World level

The world situation and outlook with regard to irrigation were the subject of numerous studies for the World Food Summit organised by the FAO in 1996. The main use made of water at world level is for agricultural irrigation, mainly in non-OECD countries (Table 1).

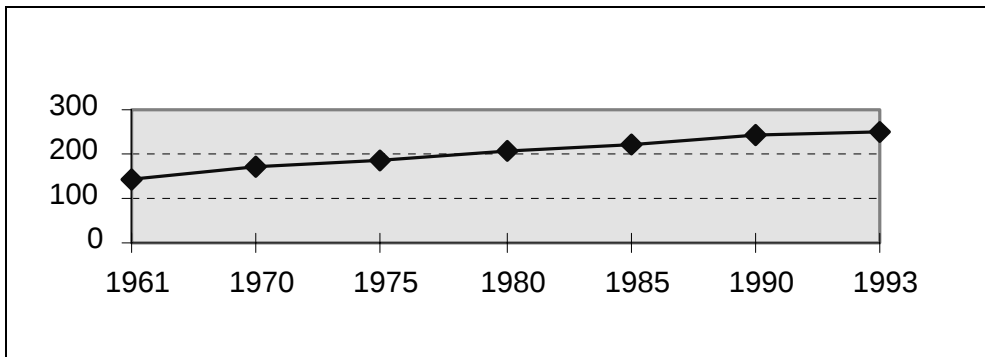
Table 1. Water use, 1990

	Agriculture %	Domestic %	Industry %	Total km ³ /an	Requirements m ³ /inhab/year
Africa	88	7	5	144	245
Asia	86	6	8	1 531	519
ex-USSR	65	7	28	358	1 280
Europe	33	13	54	359	713
North and Central America	49	9	42	697	1 861
Oceania (incl. Australia)	34	64	2	23	905
South America	59	19	23	133	478
World	69	8	23	3 240	644

Source: World Resources Institute, 1994.

Irrigation also accounts for the vast bulk of water consumption, most domestic and industrial water being returned to the natural environment. Although information on actual consumption at world level is somewhat scarce, it can be estimated from the WMO's (World Meteorological Organisation) review of the data available in the various United Nations agencies that irrigation accounts for over 90 per cent of the water abstracted from natural sources. FAO statistics show that irrigation has been increasing steadily over the last 30 years (Figure 1).

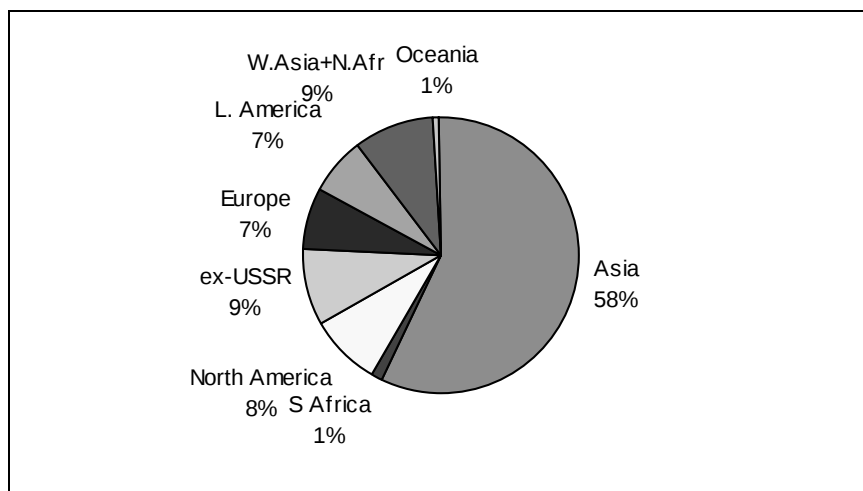
Figure 1. World irrigated area (mio ha)



Source: FAO.

Over half of all irrigated areas are concentrated in Asia, China, (India, Indonesia, Pakistan and Thailand) (Figure 2). The countries of the Middle East and the Mediterranean basin (Egypt, Iran, Italy, Spain, etc.) also account for a large proportion of irrigated land, as do some countries in the Americas (Mexico, United States, etc.).

Figure 2. Areas irrigated



Source: FAO.

The 1993 ICID (International Commission of Irrigation and Drainage) Congress revealed:

- the very poor level of irrigation efficiency (20-30 per cent) in countries with the longest history of irrigation and the low efficiency levels (30-50 per cent) in most other countries;
- the lack of knowledge on how to determine water needs for crops;
- the inadequate watering of crops;

- widespread excessive irrigation contributing to waterlogging and salt build-up;
- the predominance of public companies in the management of irrigation systems and serious reservations about the development of private bodies run by farmers themselves;
- the absence of a comprehensive water management system.

Irrigated farming on 17 per cent of land under cultivation accounts for 40 per cent of food for human consumption. The increase in production to meet demand for food comes mainly from more intensive farming and not from an increase in farmland. The potential for intensifying irrigated land is much greater than in the case of rain-fed land, the best land available for rain-fed farming being already in use, so that any development of this system would have serious effects (deforestation, erosion, etc.).

The FAO estimates that by the years 2015 to 2025, 40 million more hectares could be irrigated to meet food supply needs. Achieving this target depends, however, on the availability of renewable water resources⁹ (about a third of precipitations), which is the main constraint on the development of irrigation (see Table 2).

Table 2. Water balances

	Runoff			Resources/inhab 1 000 m ³ /year		
	Volume km ³	%	spec. capacity l/km ²	1960	1980	2000
Africa	4 570	10	4.8	16.5	9.4	5.1
Asia	14 410	32	10.5	7.9	5.1	3.3
Australia	348	1	1.4	28.4	19.8	15.0
Europe	3 210	7	9.7	5.4	4.6	4.1
North and Central America	8 200	18	10.7	30.2	21.3	17.5
Oceania	2 040	5	51.1	132.0	92.4	73.5
South America	11 760	27	21.0	80.2	48.8	28.3
World	44 538	100	10.4	13.7	9.7	7.1

Source: World Meteorological Organisation.

It is usually considered that the resources available for human activities are less than 40 per cent of renewable resources and that serious water constraints arise as soon as the threshold exceeds 20 per cent. The FAO estimates that about 2 000 m³ of water per inhabitant per year are needed to feed the world's population. The annual availability of water per inhabitant decreased from around 14 000 m³ in 1960 to less than 10 000 m³ in 1980, and a further decrease to 7 000 m³ is expected by year 2000 (Table 2). By combining these indicators it can be seen that Africa, Asia and Europe are faced with serious water management difficulties and that some countries will be short of water by the

9. Renewable water resources can be estimated from a record of river inflows into the sea or from the difference between rainfall and evapotranspiration. The data are adjusted for inflows and outflows of water between countries.

year 2000. This is particularly the case of all the countries on the southern side of the Mediterranean, some of which are in danger of “using up” their renewable resources.

An improvement in food supplies requires a marked increase in the agricultural output of water, i.e. in the quantity of farm produce per unit volume of water harnessed. Current irrigation efficiency at world level is very low (less than 25 per cent). The FAO considers that improved irrigation management, meaning an improvement in the quantity of farm produce per m³ of water supplied is one of the priorities in the years ahead (the FAO is proposing a 20 per cent increase in irrigation efficiency).

These constraints suggest that there is a need to:

- set up systems for the optimal allocation of resources, particularly in order to meet domestic needs (drinking water and public health);
- build large and costly public infrastructure systems — dams, canals and aqueducts — so as to be able to develop new irrigated areas;
- invest in the improvement of existing systems and their operation.

OECD area

A review of OECD countries (Table 3) shows that the proportion of irrigated areas is particularly high in countries with a long-standing tradition of irrigated farming (Japan, Spain). Although the growth of irrigation world-wide levelled off after 1975 because of the increased cost of new projects, a marked pick-up in irrigation is to be noted in some OECD countries. This is particularly true of France, Mexico and Turkey, where the use of sprinkler irrigation has accelerated with the creation of new plant varieties. Irrigation has also been developed as a supplementary source of supply in new locations that do not have the climatic characteristics of dry countries (Denmark, northern France, the Netherlands).

This diversity explains the difficulty of assessing irrigation efficiency, since old basin irrigation systems with an efficiency of under 30 per cent exist alongside modern sprinkler or drip irrigation systems with an efficiency of over 80 per cent, and also supplementary irrigation systems.

Agricultural factors

The amount of water needed by crops depends mainly on evapotranspiration and rainfall. However, more efficient use is made of water in cases such as fruit grown in orchards and vegetable cropping and, in the case of cereals, by rice and maize. Large quantities of water are used for alfalfa hay, pastureland in many countries (such as Mexico, the United States and, to a lesser extent, Spain). For example, Figure 3 illustrates the water requirements of the main crops grown in the United States.

Table 3. Irrigated areas in OECD countries

1 000 ha	Irrigated areas (IA)							Arable area in Use (AAU)	IA93 /AAU	Incr- ease in IA
	1961	1970	1975	1980	1985	1990	1993		(%)	93/61 (%)
USA	14 000	16 000	16 690	20 582	19 831	19 300	20 700	189 900	0.11	1.48
Mexico	3 000	3 583	4 479	4 980	5 285	5 600	6 100			2.03
Turkey	1 310	1 800	2 200	2 700	3 200	3 600	3 674	27 900	0.13	2.80
Spain	1 950	2 379	2 818	3 029	3 217	3 402	3 453	20 500	0.17	1.77
Japan	2 940	3 415	3 171	3 055	2 952	2 846	2 782	4 600	0.60	0.95
Italy	2 400	2 400	2 400	2 400	2 425	2 711	2 710	12 000	0.23	1.13
Australia	1 001	1 476	1 469	1 500	1 700	1 832	2 107	48 900	0.04	2.10
France	360	539	680	870	1 050	1 485	1 485	19 200	0.08	4.13
Korea	1 150	1 184	1 277	1 307	1 325	1 345	1 335			1.16
Greece	430	730	875	961	1 099	1 195	1 314	3 900	0.34	3.06
Canada	350	421	500	596	748	718	710	41 400	0.02	2.03
Portugal	620	622	625	630	630	630	630	3 200	0.20	1.02
Netherlands	290	380	430	480	530	555	560	900	0.62	1.93
Germany	321	419	448	460	470	482	475	12 400	0.04	1.48
Denmark	40	90	180	391	410	430	435	2 600	0.17	10.88
N. Zealand	77	111	150	183	256	280	285			3.70
Sweden	20	33	45	70	99	114	115	2 800	0.04	5.75
UK	108	88	86	140	152	164	108	6 700	0.02	1.00
World	139 389	167 902	188 147	209 701	223 828	241 548	248 125	1 444 200	0.17	1.76

* Countries are ranked in decreasing order. Those OECD countries for which irrigated areas are less than 100 000 ha do not appear in this Table.

Source: FAO.

Irrigation techniques

The conventional basin irrigation (over-flooding and runoff) system is still the predominant technique in developing countries, especially in Asia and in some OECD countries (United States: 50 per cent of the total area, Spain: 59 per cent). Even when the water is recycled over a number of fields, this is not a very efficient system because of the high losses through evaporation and seepage in the irrigation canals and fields, especially in upland fields. In the United States, basin irrigation, which was encouraged by advantageous prices and abundant water supplies, was the main technique until the mid-1970s; from then on, the strains on water resources led to greater use of pressurised irrigation systems.

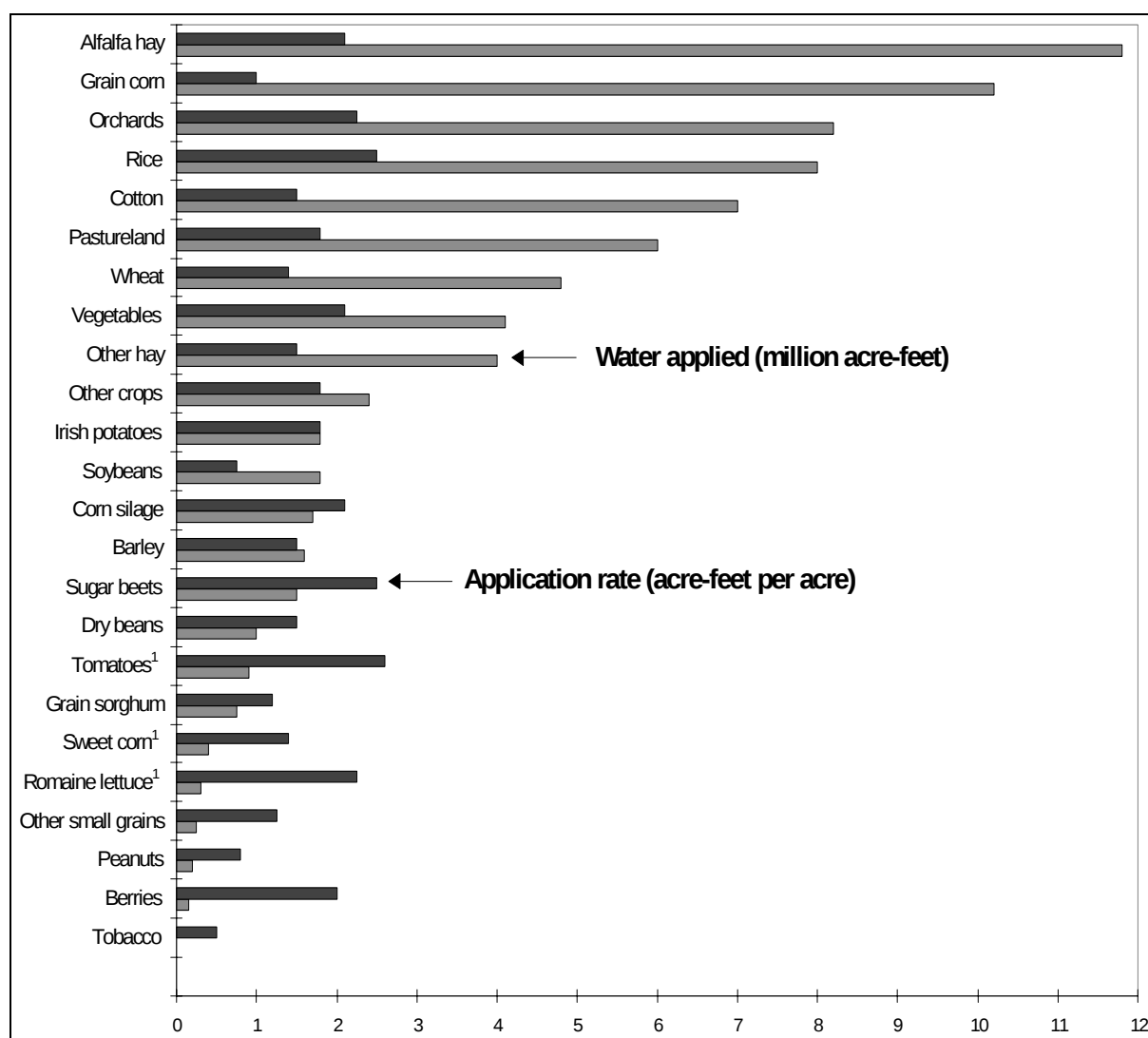
The systems introduced as of the mid-1970s in the developed countries mainly used sprinkler irrigation (efficiency in excess of 80 per cent) and, in certain cases, drip irrigation systems (fruit trees, vegetable growing). In France, over 80 per cent of irrigation is by sprinkler. These systems expanded rapidly as a result of the introduction of new plant varieties which could be grown outside the areas where certain crops thrived naturally. This was the case of sorghum, rape and especially maize which is now grown everywhere in France, whereas in the past its natural terrain was the warm and wet regions of the South West. These extended crop areas need abundant supplies of water and fertiliser to produce high yields. Within the same geographical area, pressurised irrigation systems use

5 to 10 times less water than basin systems. Because of the strain on water resources, it would seem that the preference in the future should be for these pressurised systems.

In virtually all countries, renewable resources are already used intensively to supply the irrigation areas. This is obvious in the case of the heavily populated regions of the Mediterranean basin. Even the Asian countries, which have plenty of rain, are relatively short of water because of their high population densities and the competing needs of rapidly expanding urban areas.

Poor irrigation efficiency at world level is to be attributed to the preponderance of traditional techniques and inadequate system maintenance. Improved systems and the optimisation of water use (regulated by means of agrometeorology warnings) are the two main possible ways of achieving higher irrigation efficiency.

Figure 3. Total water applied and average application rate by crop, United States, 1994



1. Also included in vegetables.

Source: USDA, ERS, based on 1994 Farm and Branch Irrigation Survey data.

Environmental effects of irrigation

Certain effects of irrigated crops are indirectly beneficial to the environment: These include the refilling of groundwater, regulation of runoffs, re-use of waste water and protection against soil erosion. The negative effects, under certain conditions, can be summarised as follows.

Water depletion

Water depletion is the most immediate effect of irrigation. Hydrological records over a long period (more than 50 years) have shown a marked reduction in the annual discharges on some of the world's major rivers: the Colorado (United States), the Don (ex-USSR), the Ebre (Spain), the Jordan (Israel, Jordan), the Murray (Australia) and the Nile (Egypt). This has resulted in serious damage to certain closed seas (the Aral Sea, the Dead Sea). These are exceptional cases, for the volumes carried during a high water flow are usually very much greater than in a low water period.

In all geographical regions, depletion is all the more pronounced when irrigation is concentrated in a few months of the year when river water levels are low. Peak irrigation abstractions usually exceed naturally low water volumes. In most of the major irrigation sectors, the necessary water volumes are obtained by withdrawals from dams or transfers between catchment basins. The construction of such infrastructure has become increasingly costly and difficult to take greater account of environmental concerns. They are often built too late, in response to the increase in new needs after natural low water flows have been sacrificed. It is only recently that the concept of maintaining minimum flows has emerged in many countries.

Soil and water pollution

Improved agricultural productivity is accompanied by an increase in the use of fertilisers and pesticides, some of which find their way into the natural environment as pollutants. From this point of view, irrigated farming is not more harmful than intensive rain-fed farming and can even bring out the best from these inputs provided their use is spaced out. However, the reduction in river flows and dilution and natural purification effects obviously have the effect of increasing soil and water pollution.

Salinisation

One of the major disadvantages caused by irrigation is salinisation. The FAO estimates that over 20 million irrigated hectares are seriously affected, and that 60 to 80 million hectares are affected to varying degrees by waterlogging and salinity. Improving drainage can reduce these effects.

Induced effects

The ICID has proposed a check-list for analysing the main environmental effects of irrigation. In addition to hydrological and water and ground pollution effects, they include the effects on:

- natural balance of rivers and aquifers, rare animals (ecology);

- drinking water supplies, water-borne diseases, nutrition (public health);
- insect pests, weeds (pest control).

Corrective measures

The main measures that can be used to limit the negative effects of irrigation on the environment can be summed up as follows:

- creation of water reserves or aqueducts;
- water savings: irrigation techniques, irrigation management (agrometeorology warning systems, water towers, etc.);
- greater control over fertilisers and pesticides; and,
- recycling of waste water.

These take the form of constraints being transferred to other users:

- diversification of abstractions for drinking water supplies;
- reinforcement of waste water treatment systems; and,
- environmental rehabilitation.

2. Measuring the impact of agriculture on water use

Indicators

Exploitation and Consumption indices

The impact of human activities on the water cycle can be expressed in terms of:

- exploitation indices: water abstraction/renewable resources;
- final consumption indices: water consumed/renewable resources.

Only a small proportion of renewable resources can be used easily: first, flows during the irrigation period are obviously much lower than the average river flows (less than 25 per cent of average annual flows); second, minimum river flows, usually amounting to over half the low-water flows, need to be maintained for ecological and hygiene reasons.

Hydrologists generally distinguish four categories of water stress based on exploitation indices. It is considered that when an *exploitation index* is:

- less than 10 per cent, there is no pressure on water resources;

- between 10 and 20 per cent, there are pressures on water resources;
- between 20 and 40 per cent, control systems must be set up (flow control structures, water savings, etc.); and,
- over 40 per cent, the pressures endanger renewable resources.

Impact of various uses

The available data are usually expressed only in terms of abstractions. Consumption is usually expressed in terms of indices per major category of use. The following consumption indices depend on the technology and the state of equipment:

- drinking water: losses (the ratio between drinking water supply and water withdrawal) of between 10 and 35 per cent;
- industry: consumption varies with the type of production between 15 per cent (paper pulp, agri-food) and less than 1 per cent (surface treatments, etc.) — average of 7 per cent in France;
- energy: between 7 per thousand (open circuit thermal power stations) and 10 to 15 per cent (closed circuit). The closed circuit is in widespread use for nuclear power stations in inland waters in western Europe;
- irrigation: basin irrigation, 15 to 25 per cent consumed by crops + system losses (30 to 40 per cent); sprinkler irrigation 75 to 80 per cent and drip irrigation 90 per cent.

These indices may be lower if the equipment is old or poorly maintained.

In the case of **abstractions**, energy is usually the main sector. In the case of consumption, irrigation is usually the main sector. Industrial needs have declined substantially owing to the cessation of certain activities (mining) and the development of recycling techniques. Population growth and increased urbanisation is resulting in numerous conflicts between domestic and agricultural needs.

Irrigation data

Data for irrigated areas are the subject of a world inventory updated by the FAO. One composite indicator of water use is the volume of water used in relation to the area irrigated. It is a very general and imperfect indicator. Knowledge of irrigation water needs means analysing crop rotations, the techniques used and system efficiency. Such data are very patchy, particularly with regard to efficiency criteria.

One relevant overall efficiency criterion would be the volume of water consumed per unit of agricultural produce obtained. A number of studies show that very significant gains can be obtained in a given agricultural/geographical context by optimising irrigation system management. Unfortunately, this indicator has only been the subject of occasional studies.

Water pollution

The amount of fertiliser per hectare (or active ingredients per hectare in the case of pesticides) is a water pollution indicator. It is also an indicator of intensive farming and is monitored in regions where intensive dry farming or intensive animal breeding is practised, as well as in irrigated areas. Nitrates, which are highly soluble and are not retained in soils, are a good agricultural pollution indicator. At the European level, the map of designated areas for the EU nitrates Directive (91/676 EEC) gives a good idea of the most contaminated regions.

With regard to irrigation, these indicators can be supplemented by a deterioration index for pollution caused by the lack of dilution: discharges (especially of town sewage and industrial effluents) in relation to available resources (renewable resources — consumption).

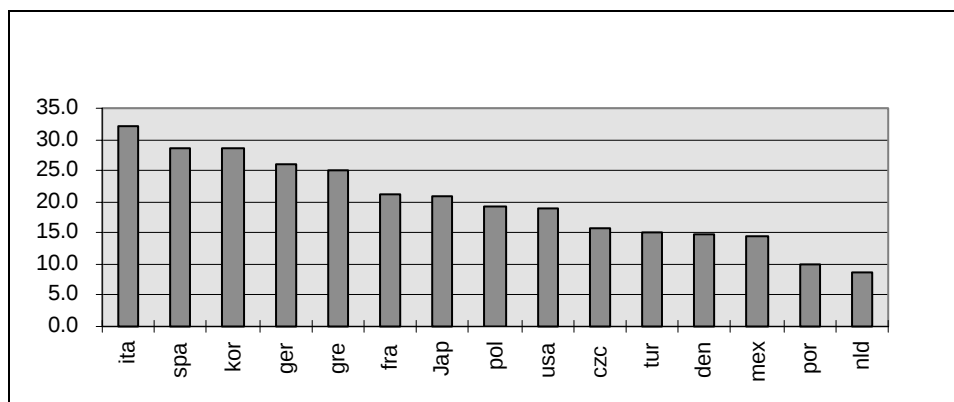
Soil

The effects of waterlogging and salinisation on soil quality are qualitatively well identified. Few quantitative data are available, but they can be correlated with the volumes of water supplied per hectare and capacity of the drainage facilities provided.

Current situation

The OECD Statistical Compendium provides information on the OECD countries' renewable resources. The OECD countries use, on average, 11 per cent of renewable resources. Seven countries use over 20 per cent of renewable resources: France, Germany, Greece, Italy, Japan, Korea and Spain (Figure 4). Eight countries use more than 10 to 20 per cent of renewable resources: the Czech Republic, Denmark, Mexico, the Netherlands, Poland, Portugal, Turkey and the United States; twelve countries use less than 10 per cent of renewable resources: Australia, Canada, Finland, Hungary, Ireland, the Netherlands, New Zealand, Norway, Slovak Republic, Sweden, Switzerland and the United Kingdom.

Figure 4. Exploitation indices (%)



Source: OECD.

Share of irrigation in the use of water resources

The countries where irrigation accounts for over 50 per cent of total abstractions are the following: Greece, Japan, Korea, Mexico, New Zealand, Spain and Turkey (Table 4). However, In many countries, only a limited part of the land is irrigated (southern France, for example). Pressures at local level are often much stronger than is reflected by national indices.

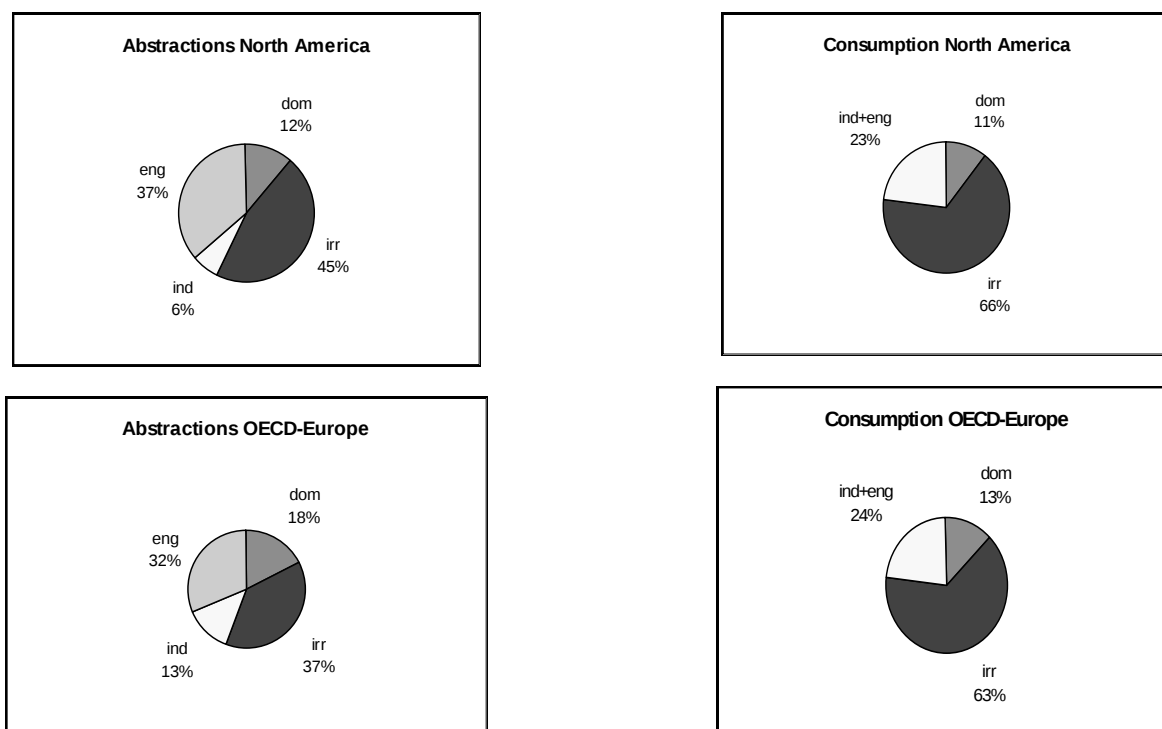
Table 4. Freshwater abstractions by source

	m ³ /hab	% of resources	Total abstractions				Irrigation/ total abstractions			
			(million m ³)				%			
	(a)	(a)	1980	1985	1990	1995	1980	1985	1990	1995 c)
Canada	1 604	1.6	37 594	42 383	45 096	..	7.4	7.0	7.1	..
Mexico	777	14.5	56 000	..	..	73 674	82.1	..	..	83.1
USA	1 875	18.9	517 720	467 335	468 620	..	38.7	40.5	40.2	..
Japan	724	20.8	88 200	88 495	90 083	90 497	65.3	65.5	64.5	64.2
Korea Republic*	533	28.5	17 510	18 580	20 600	23 700	80.5	76.4	68.4	62.9
Australia	844	4.3	10 900	14 600	..	15 055	74.3	69.9	..	..
N. Zealand	575	0.6	1 200	1 900	..	2 000	..	..	..	55.0
Austria	282	2.7	2 190	2 120	2 360	2 250	2.3	2.6	8.5	8.9
Belgium	..	..	9 030	..	..	..	..	..	..	..
Czech Republic	244	15.8	3 365	3 440	3 396	2 520	1.2	1.5	2.9	1.2
Denmark	170	14.8	1 205	..	1 173	887	..	..	25.6	15.8
Finland	479	2.2	3 700	4 000	2 347	2 437	..	0.5	0.9	..
France	702	21.3	35 104	34 898	38 287	40 641	12.5	12.8	12.9	12.1
Germany	579	26.0	42 206	41 216	46 272	..	..	..	..	..
Greece*	*699	*25.0	5 040	..	..	*7 030	82.5	..	..	*80.5
Hungry	610	5.2	4 805	6 267	6 263	6 259	7.0	4.6	8.5	4.6
Iceland	614	0.1	100	103	164	164	0.0	0.0	0.0	0.0
Ireland	329	2.3	1 070	..	..	1 176	12.1	..	..	15.2
Italy*	992	32.2	56 200	52 000	56 200	*45 000	57.3	..	..	*71.8
Luxembourg	137	3.4	..	67	59	57	..	..	0.3	0.4
Netherlands	518	8.6	9 197	9 302	7 806	..	..	..	..	..
Norway	..	..	..	2 025	..	..	..	3.4	..	..
Poland	313	19.2	14 184	15 453	14 248	12 066	2.0	3.4	3.3	1.7
Portugal	735	10.1	..	..	7 288	..	..	..	52.6	..
Spain	849	28.7	39 920	46 250	36 900	33 288	65.7	65.7	64.2	72.4
Sweden	309	1.5	4 106	2 970	2 968	2 725	1.6	3.2	3.2	3.9
Switzerland	369	4.9	2 589	2 646	2 665	2 595	..	..	..	..
Turkey	569	15.0	16 200	19 400	32 200	35 100	..	73.7	53.9	69.3
UK	228	..	14 496	12 947	14 237	11 752	0.6	0.6	1.3	1.2
Slovak Rep.	264	1.7	2 232	2 061	2 116	1 406	..	5.9	12.6	7.9
North America	1 520	10.0	611 300	572 000	581 700	587 400				
OECD Europe	580	15.0	272 900	280 500	295 100	290 500				
EU — 15	620	21.0	229 600	231 200	238 200	229 600				
OECD	930	11.0	1 002 000	976 100	1 004 000	1 009 200				

Source: OECD data, completed by data from Blue Plan (*).

Data on the consumption of water withdrawn from the natural environment are very patchy. Most industrial and domestic water supplies are restored to the natural environment (particularly in the energy sector), whereas a large proportion of irrigation water is “consumed” by evaporation or the crops grown. The share of irrigation in total estimated consumption is lower in North America and in western Europe than in Asia (Figure 5). Regional studies show, however, that irrigation accounts for over 85 per cent of consumption in the major irrigation regions (California, Colorado, south-west France, Mexico, southern Spain).

Figure 5. Freshwater abstractions and consumptions



Source: Table 4.

Source: Estimations from OECD data.

Note: dom: domestic uses; eng: energy; ind: industrial uses; irr: irrigation.

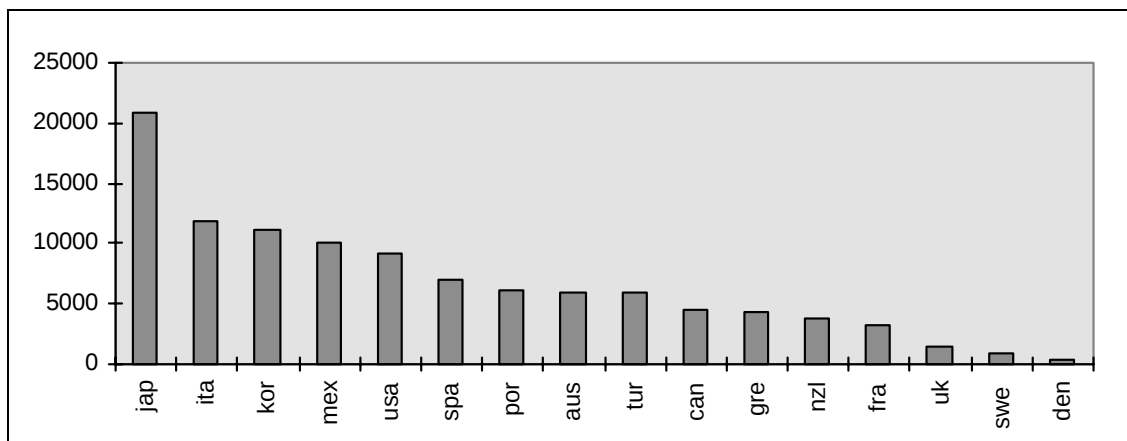
A review of the last 30 years points to a number of converging trends. In the most highly developed countries, the last 20 years have been marked by a substantial reduction in industrial requirements for water, a considerable increase in energy sector needs — although these are now levelling off, and, more recently, the stabilisation of domestic needs. Withdrawals for irrigation purposes in these countries, especially in the last 10 years, have resulted in induced pollution effects and substantial additional costs to meet drinking water needs. Extensive infrastructure works are therefore required to maintain flows that will keep rivers clean and meet new irrigation needs.

In developing and some OECD countries, domestic needs are still rising rapidly. Irrigation very often competes with the needs of towns (urbanisation) and industrial development. This is the case of the Mediterranean basin countries, Korea and Mexico.

Irrigation efficiency

The wide range of water volumes withdrawn per hectare can be illustrated by combining FAO data on irrigated areas and OECD data on abstractions for irrigation (Figure 6).

Figure 6. Irrigation abstractions (m³/ha)



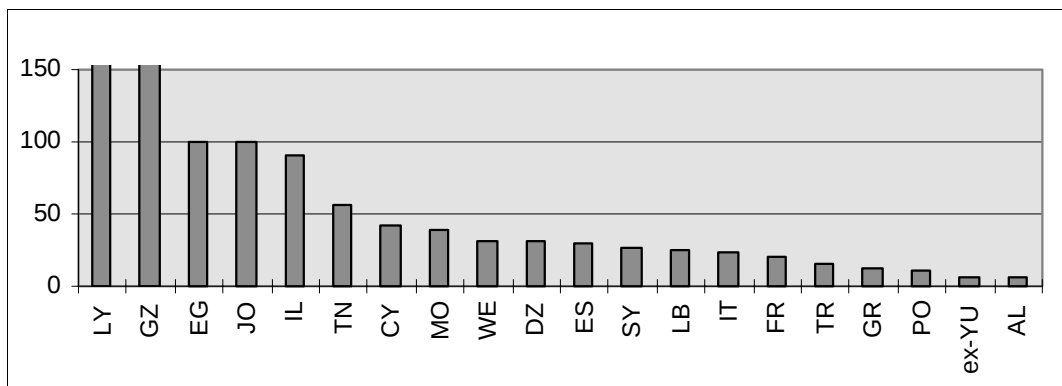
Source: FAO and OECD.

This very broad indicator makes it possible to classify countries by irrigation type: mainly basin irrigation, pressurised irrigation and irrigation on a supplementary basis. Such an indicator should reflect the volumes consumed per hectare or the volumes per unit of agricultural produce obtained. It should be noted that in Japan, large quantities of water for paddy irrigation are re-used in downstream, which improves the overall water management efficiency.

The case of Mediterranean countries

In addition to the indirect effects referred to earlier, irrigation leads in many countries to an imbalance

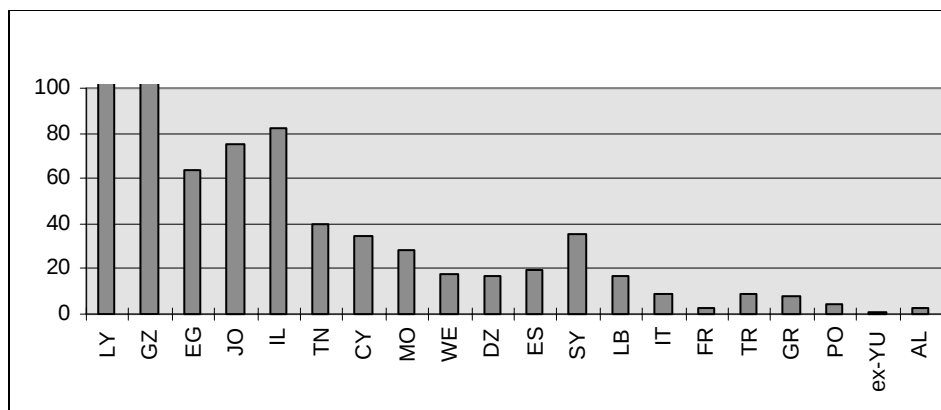
Figure 7. Exploitation indices



Source: Blue Plan.

in overall water resource management and to numerous conflicts over use. The report drawn up under the Blue Plan for the Euro-Mediterranean Conference of 1996 shows that more than 7 southern Mediterranean countries have exploitation indices close to or in excess of 100 per cent and consumption indices close to or in excess of 80 per cent, which reflects a decline in renewable resources (Figures 7 and 8).

Figure 8. Consumption indices



LY-Libya, GZ-Gaza, JO-Jordan, SY-Syria, TN-Tunisia, WE-West Bank, SP-Spain, LB-Lebanon, TR-Turkey, PO-Portugal, DZ-Algeria, MO-Morocco, AL-Albania, IT-Italy, FR-France, GR-Greece, IL-Israel, CY-Cyprus.

Source: Blue Plan.

The situation in the Mediterranean area is typical of a region where conflicts over water resources have not been resolved. Water resources are usually not allocated on an optimal basis. The cost of the associated infrastructure is seldom passed on to users.

3. Irrigation costs

Investment

Costs directly related to irrigation come under four main headings:

- joint networks for water resource management;
- joint networks for delivering water to fields;
- farmers' individual systems; and
- networks operation.

Table 5 gives some reference data on the investment costs of recent sprinkler irrigation systems in France, designed to meet average needs of 1 500 m³/ha.

Table 5. Investment cost of irrigation systems

	Areas with water shortages — N°1	Areas with abundant water — N°2	Intermediary areas, surface water — N°3	Aquifers with abundant water — N°4
	Joint network	Joint network	Individuals	Individual
Creation of resource ¹ (FF/m ³)	8 à 12	0	6	0
Drilling, pumping, networks ² (FF/ha)	34 000	30 000	2 000	3 330
Movable equipment (FF/ha)	2 850	2 850	2 850	2 850

1. Dam — FF 8/m³, aqueduct — FF 4 to 6/m³, hill impoundment pond — FF 6/m³.

2. Large joint terrace networks on the sides of valleys (N°1 and N°2); Individual pumping from river banks or surface aquifers (Landes) (N°3), Beauce-type pumping at 40m (N°4).

Source: Jean Luc Redaud, 1997.

Cost of a cubic metre of water

It is possible to work out a theoretical estimate of the cost of a cubic metre of water by taking into account the investment and operating costs and depreciation (25 years for water resource systems, 10 years for fixed capital, 6 years for movable equipment) and applying a discount rate of 8 per cent (which is the rate applied in France) (Table 6). On major joint irrigation sites, “production costs” for most of the networks recently introduced in France are between FF 2.5 and 3.5/m³ (US cents 42 to 58/m³).

Table 6. Theoretical cost of a cubic metre of water

Location	N°1		N°2		N°3		N°4	
	FF/ha/yr	FF/m ³	FF/ha/yr	FF/m ³	FF/ha/yr	FF/m ³	FF/ha/yr	FF/m ³
1. Creation of resource	1 120	0.75	0	0	840	0.56	0	0
2. Drilling, pumping, networks	2 800	1.80	2 200	1.45	300	0.20	500	0.33
3. Movable equipment	600	0.40	600	0.40	600	0.40	600	0.40
Total depreciation (1+2+3)	4 520	2.95	2 800	1.85	1 740	1.16	1 100	0.73
4. Operating costs	600	0.40	600	0.40	400	0.40	800	0.53
Total (1+2+3+4)	5 120	3.35	3 400	2.25	2 140	1.56	1 900	1.26

Source: Jean Luc Redaud, 1997.

Induced costs

It is more difficult to measure induced costs. Knowledge of the full economic losses caused by excessive use of water resources is still lacking. It requires a definition of the ecological management objectives from which the rules for public management of the natural environment are derived: minimum river flows, quality targets and the protection of wetland habitats. It has still to be

decided how the cost of the measures to restore or manage this natural environment should be shared among users.

Some induced costs can, however, be identified in terms of the corrective measures needed because of excessive use of natural resources:

- maintenance of minimum flow rates: FF 8 to 12/m³ (US\$1.3 to 2/m³);
- denitratation of water (FF 2/m³ [US\$0.3/m³]), waste water purification (FF 2 to 5/m³ [US\$0.3 to 0.8/m³]);
- desalinisation of sea water: FF 5/m³ (US\$0.8/m³); and
- diversification of water resources.

Financing

The results of an OECD survey showed that irrigation was to a large extent subsidised by governments, although these data must be interpreted with caution, since they date back from the early 1980s and measurement methods vary by country (Table 7). Since then, many countries have shifted the focus of their aid from the creation of major infrastructure to a comprehensive system of water resource management. Fixed irrigation equipment (pumping systems, joint networks, etc.) is usually eligible for local authority aid.

Table 7. Equipment subsidy rates in the early 1980s¹ (%)

	Government	Local authorities	Residual cost
Canada	50	50	
France	50		50
Japan	45-60	10-25	20-45
New Zealand	70		30
USA		60	40

1. Excluding interest concessions.

Source: OECD, 1987.

Equipment subsidies are often supplemented by low-interest loans from the authorities. In addition, equipment subsidies are supplemented by subsidies to operating costs in the form of low cost of water and/or energy consumption. It is very difficult to obtain information on subsidies for irrigation.

In Mexico, government subsidies to irrigation for the NCW (National Commission for Water) totalled more than US\$500 million in 1993, together with equipment subsidies. Farmers also pay subsidised prices for the electricity they use for pumping.

In the United States, ancient systems of water rights and very long-term contracts favourable to farmers ensure that substantial vested interests and very low charges remain in place. In the Central Valley project in California, for example, the contracts provide for charges ranging between US\$0.003 and US\$0.013/m³, which are far lower than those for the new systems (US\$0.16/m³) which

are mainly financed by the local authorities. Farmers mostly pay a price based on the area rather than the volume of water supplied (for example in the West, the Bureau which acts as a distributor for a quarter of the irrigated areas charges about US\$85/ha a year for a subsidised expenditure of US\$135/ha). There is no charge for the actual volume of water.

In Japan, over 50 per cent of investment expenditure is subsidised by the government and Prefectures (OECD, 1989). A quarter of irrigation districts used to receive municipal subsidies to cover operating and maintenance costs (Heckelmen *et al.*, 1994), although most districts are now operated on a self-financing basis. There does not seem to be any system of pricing by volume.

In France, between 1979 and 1989, investment in irrigation backed by government aid totalled FF 8 700 million (around US\$1 400 million). Volume charges and metering are the rule for joint networks. Water resource infrastructure (dams, aqueducts) is usually 100 per cent financed by the local authorities, with assistance from central government and the Water Agencies. Central government no longer provides aid for network equipment which is subsidised by the local authorities. Agricultural organisations should cover operating costs and maintain and modernise equipment which come under their responsibility. A decrease in public subsidies, results in increasing costs which vary from FF 0.5/m³ to FF 1.5/m³ (US cents 8 to 25/m³).

In the Netherlands, abstraction is free for the use of surface water and very cheap for underground water (US\$0.006/m³).

In Spain, a very extensive dam construction programme financed by government appropriations was carried out between 1950 and 1970, especially in the southern part of the country, which currently holds two-thirds of the national water storage capacity (excluding hydropower reservoirs). In the last years of extreme drought, this did not prevent serious conflicts arising between the growing needs of towns, tourism and irrigation, particularly in southern Spain. Under the national irrigation plan, the government had set to spend about Ptas 600 billion (US\$4.5 billion) over the period 1996-2000, mainly in order to modernise existing infrastructure, but also to extend the area under irrigation. However, this plan is being revised with a view to achieving a more efficient use of water resources. The price of water is cheap and is based on area rather than the volume withdrawn. In areas irrigated by gravity with regulated waters, prices range from Ptas 12 000/ha (US\$90/ha) [traditional system] to Ptas 20 000/ha (US\$150/ha) [modern system], i.e. from Ptas 6 to 8.5/m³ (US cents 4.5 to 6.4/m³), while in areas where water is pumped, the cost of water may range from Ptas 60 000/ha (US\$450/ha) to Ptas 150 000/ha (US\$1 125/ha).

In Turkey, the target set in 1990 was to increase the area of irrigated land by 53 per cent by 1994, thanks to work carried out by government agencies. Prices are kept quite low as the electrical power for pumping is subsidised.

Generally speaking, in most countries it can be observed that:

- collective structures (dams, aqueducts) are the responsibility of the authorities, governments considering that they have a physical planning impact on the region and financing these operations from local or national taxes;
- joint network equipment is subsidised in the order of 30 to 70 per cent; and
- farmers themselves finance movable equipment.

4. Water pricing

Under-pricing of irrigation water tends to be the rule. In many countries, large collective networks are managed by public bodies or State companies (Mexico, Turkey): the price of water is more of a political trade-off than an accurate reflection of costs. Under-pricing leads to revenue shortfalls, resulting in poor maintenance, substantial water losses and delays on new projects. In traditional basin irrigation systems, flat rates are usually charged (water right), which does not encourage economical use of water.

Objectives

The basic principles applied vary greatly across countries. The different systems in use can briefly be described as follows:

1. coverage of network operating costs only, in order to increase farm income (socio-political pricing);
2. coverage of operating costs and full or partial refund of public investment so that farmers participate to a greater or lesser extent in gross fixed capital formation;
3. marginal cost pricing, to make the farmer pay the real cost of water and encourage its optimal use;
4. pricing to make the farmer pay for irrigation services, but also for the provision of amenities (cleaning of rivers, maintenance of minimum flow rates, etc.); and
5. pricing that covers a sustainable management of irrigation systems: operating costs, upkeep and modernisation of equipment.

The theory of marginal cost pricing is based on the notion that prices must:

- in the long term, avoid deficits for network managers and enable them to adapt network structures to foreseeable future needs;
- impress on farmers what the real cost of water is; and
- ensure the optimal use of networks.

For a set of irrigation systems covering a region or a country, the marginal cost is the cost of the latest networks built or planned. It is likely to be higher than the cost of existing networks since water resources which can be easily tapped tend to be already harnessed and sites that are easy to irrigate already equipped. In addition, it would seem legitimate to ask farmers to share in the community costs of managing the water resources from which they benefit more than others.

Marginal cost pricing of irrigation systems should, in principle, be supplemented by marginal cost pricing of collective facilities; i.e. of the cost of development work which must be carried out to ensure joint, balanced use of natural resources by all, and by the costs of managing and protecting these resources (low-water flow maintenance structures, river engineering, etc.).

Acting on these principles, France has introduced, in addition to charges for services provided, a system of Water Agency charges to finance public water resource operations. In principle, all users have the same rights with regard to natural resources (subject to the protection thereof) and pay charges under a system which takes only abstractions or pollution of the natural resource into account.

The majority of countries apply a tarification system, where the objective is only to cover, either wholly or in part, the operating cost. The principal of tarification at marginal cost price, is not applied as it not adapted to an economic context, for irrigated crops. Certain countries apply a tarification system to cover a sustainable management of irrigation systems.

Pricing systems

The main pricing systems used in OECD countries comprise:

- Collective charges for the use of *natural resources*, the aim being to contribute to optimal allocation of available resources. These charges, which are collected by central government or, in some cases, by the basin agencies, are levied on all water users. They have been introduced in only a very limited number of countries; and,
- Charges for *services* provided by irrigator associations fully or partly responsible for the management of systems, the aim being to cover part of the direct costs of services. In many countries, irrigator associations are being replaced by public utilities, however, a general improvement in the partial or total responsibility given by irrigating associations can be observed.

Pricing systems for services provided can be divided into two main categories:

- flat-rate charges: this is the usual system for basin irrigation;
- charges based on abstraction volumes: this is the usual system for sprinkler or drip irrigation.

Volume-based pricing systems are on the increase: they sometimes use a two-part formula and a system of incremental pricing above the base volume corresponding to optimal use of the network to meet crop needs (*Compagnie d'Aménagement des Côtes de Gascogne* [CACG] restoration agreements).

Along with these systems, greater use is being made of metering devices. With metering it is possible to optimise the use of agrometeorological warnings and save considerably on water. Metering can be extended quite easily on joint systems, but is still limited on individual systems.

Irrigation pricing and costs

Information on the prices charged shows that, except in the few cases where resources are abundant and easily accessible, only a small proportion of irrigation costs are covered by the charges. When there are no charges for access to natural resources, induced costs are not passed on. Where they do exist, the charges are “adjusted” to the advantage of farmers.

Charges for services provided are generally reduced to a level dictated by socio-political considerations. *In collective irrigation systems, it is estimated that these charges usually cover less than a third of construction, depreciation and operating costs, not including the cost of major water resource infrastructure.*

When pricing is based only on the contract area with allocated volumes of water (“use or lose”) and prices are based on obsolete historical data, only a very small proportion of irrigation costs is usually covered.

Example of France

Irrigation is a long-standing tradition in France’s Mediterranean regions. Starting in the 1970s, it developed extensively in the south-west as more maize was grown, which resulted in serious water shortages and the need for a dam and aqueduct construction programme. More recently, irrigation has developed in northern France as a supplementary supply source.

In the past, equipment were heavily subsidised by the government, which recently transferred the responsibility for water resources to the Water Agencies and, for other equipment, to local authorities (Table 8). The price of water charged to irrigators, includes:

- charges for withdrawal of water from natural sources, which go to the water agencies;
- taxes for services which go to local irrigation organisations.

Table 8. Financing of equipment (%)

	Government	Local authorities	Water agencies	Irrigators
Infrastructure and large dams	30 à 50	30	30 à 50	
Hill impounded lakes		20 à 30	20	60
Pumping, networks		30 à 50	0	50 à 70
Surface equipment				100

Source: Jean Luc Redaud, 1997.

Charges for water agencies

The water agencies are publicly-owned bodies with financial autonomy. In consultation with local authorities and water users, their role is to finance community ventures in major catchment areas through water user charges. In the case of water resources, these operations concern stocks for maintenance of the low water level, aqueducts, the optimisation of underground water management, river development, water savings and the protection of drinking water supplies. The water agencies provide between 30 and 50 per cent of the funds needed for these projects.

The collective costs met by users as a whole for water resource management are partly “internalised” by the Water Agencies. Irrigators pay the Water Agencies a charge of about 2.5 to 5 centimes/m³ (0.4 to 0.8 US cents/m³). This charge is much lower than those paid by other users and than those which take infrastructure costs into account (annual discounted value of storage dams of about 60 to

80 ct/m³/year (10 to 13 US cents/m³/year), or the theoretical cost of access to water from replenished rivers).

In principle, all users must share some of the marginal cost of balanced, environment-friendly access to natural resources. This principle is applied only partly, a substantial proportion of investment still being covered by central and local government subsidies. In addition, farmers pay reduced charges compared with the local authorities distributing drinking water and industrial users. The charges paid by irrigators to the Water Agencies are, however, an important step towards some internalisation of the costs to the community deriving from irrigation.

Taxes for the provision of services

Irrigators in collective networks usually belong to authorised professional associations (*Association Syndicale Autorisées* [ASA]) which have to cover the cost of the network and depreciation out of the prices charged to their members. Farmers pay directly only for investment in movable equipment.

Private companies (where stock-holders are the local authorities or agricultural organisations) manage major collective irrigation sectors with the use of large-scale facilities that are financed out of government appropriations in the Mediterranean region (*Compagnie Nationale du Bas-Rhône-Languedoc* [CNBRL], *Société du Canal de Provence* [SCP]) and, in the south-west, (CACG).

Both the ASAs and the irrigation companies are required to cover, through the price of water, the costs (after deduction of first equipment subsidies) of the irrigation sectors run by them. They usually invoice water in proportion to the volumes distributed. They encourage economical use of water by installing meters (70 per cent subsidised by the Water Agencies) and setting up agrometeorological warning systems.

For example, the CACG, which manages large-scale systems in areas with a water deficit, sets a price comprising three components:

- a charge which is proportional to the contract flow and is split between the irrigators on the basis of the volume quota allocated to each irrigator; these quotas being aimed at optimising the use of available resources;
- an increasing charge for consumption exceeding the contract volumes, aimed at discouraging non-economical use of water; and
- a meter rental.

The price of pressurised water delivered to the field hydrant is between FF 0.8 and FF 1.2/m³ (US cents 13 to 20/m³). This price is almost equivalent to those applied in the majority of principal collective irrigation organisations.

The financial constraints of ASA and companies to balance their budgets without public subsidies oblige them to establish prices, to cover the overall operating, maintenance costs and the modernising of equipment, i.e. *a sustainable maintenance* of the sectors for which they are responsible. However, as long as the price of water is invoiced at less than FF 1/m³ (US cents 17/m³), the benefits are unable

to cover a large part of the cost of the first investment. As a result, it is necessary to maintain large public subsidies for the creation of water reserves necessary for irrigation.

Irrigation water prices

The difficulty of charging equipment costs to irrigation water may derive, in some cases, from the low value added of agricultural activities. Table 9 gives some information on gross margins for dry and irrigated crops in France. This Table shows that if the full costs of irrigation under joint irrigation systems were passed on to farmers, their gross margins would be lower than those obtained from rain-fed crops.

Table 9. Gross margins in 1990 (FF/ha/year)

	Reference yield tonnes/ha	At 1990 prices without irrigation charges	With irrigation charges of FF 5 120/ha (US\$853/ha)	With irrigation charges limited to FF 1 500/ha (US\$250/ha)
Hard wheat	6	4 800		
Soft wheat	6	3 000		
Dry maize	4.5	3 400		
Irrigated maize	8.5	7 500	2 380	6 000
Dry sorghum	4	4 200		
Irrigated sorghum	5	5 200	80	4 700
Dry sunflower	4	3 400		
Irrigated sunflower	5	5 200	80	4 700
Arboriculture		25 000 to 150 000		

Source: Jean Luc Redaud, 1997.

Another indication of the difficulty of irrigators paying for water is that it is difficult for joint network managers to negotiate regular price rises, which therefore often do not keep up with general price rises. Price increases for agricultural products have been generally lower than for prices in general, and do not therefore facilitate the price adjustments that need to be made. However, a full economic picture ought to take into account the overall level of support granted to farmers.

Irrigation flexibility: elasticity of demand

The data on price elasticity of water for irrigation, are patchy but coherent. Studies conducted in the United States and Australia show, for various crops, the elasticity of demand for irrigation water in the region of -0.1 to -0.5 below the average price and elasticities of -0.5 to -2.3 above the average price. Negative responses to price increases are greater than in the domestic and industrial water sectors. Water accounts for less than 5 to 10 per cent of a household's annual budget, and even in industries where water consumption is heavy, the corresponding costs are still less than 10 per cent (and usually 5 per cent) of operating costs, whereas irrigation may account for 25 per cent of farmers'

operating costs. Rational use of inputs (fertilisers, pesticides) is usually accompanied by good water management.

Against this, it must be remembered that the steep increases in the price of drinking and sanitation water in urban areas lead in some cases to a refusal by town dwellers to meet the financial costs of the systems often made necessary by the excessive use of natural water by farmers. For example, it has become difficult in France to persuade users that the water supply authorities have to contribute to the funding of new water stocks in response to the fall in the low water level of certain rivers, which is mainly attributable to irrigation.

The experience in France suggests that irrigation can be developed only if equipment is highly subsidised, and in France it is believed that irrigators cannot afford to pay more than FF 1 to 1.5/m³ (US\$ cents 17 to 25/m³) for water. These comments might suggest that irrigation should be developed only in areas which can be easily equipped and have abundant water supplies within easy reach.

However, there are many reasons why this is not the case:

- irrigation provides security against the risks inherent in rain-fed crops in regions subject to periodic drought; and
- irrigation contributes to higher agricultural output by increasing yields, and therefore to a country's food security.

The water market, an alternative or supplement to pricing?

The market can help to optimise joint management of water utilisation, particularly in the context of operations to save water in agriculture through extensive modernisation of irrigation networks. In the United States, voluntary exchanges of water rights involving transfers from irrigation companies to power companies or municipal water utilities have taken place in a number of western states (California, Colorado, Utah). In South Australia, the liberalisation of water rights in the Murray River basin has resulted in the transfer of 3 900 million m³ a year, or about 5 per cent of previously existing water rights. In New South Wales, 5 per cent of the surface water used in the state has been transferred.

It would seem, however, that these operations have to be closely controlled by the authorities (basin authorities) in order to prevent the water necessary for the natural environment from being sacrificed, or to prevent dominant positions among buyers capable of setting a price for water that farmers cannot pay.

5. General findings

Towards comprehensive water management

Pricing is a useful way of encouraging a rational approach to irrigation, but is not sufficient as an economic signal in cases where low prices for farm output and a low level of support mean that farmers can not afford to pay the full economic costs.

Water shortages have led many associations of irrigators to set up quota systems in order to distribute limited resources on an equitable basis. These “water rights” systems have been in use for a very long time in certain rural communities, like the “water courts” system in southern Spain.

To encourage the efficient use of water, it would seem desirable that these systems should continue to be jointly managed by farmers themselves at the local level, and that the price of water be based on the volume withdrawn. The authorities’ main role is to create new distribution systems by means of water use regulations, and to organise the basis of comprehensive water management system applicable to all users. Owing to the new environmental awareness and the many past disorders resulting from the excessive use of water resources, the authorities are increasingly including environmental protection rules within this general regulatory system, an example being the minimum flows to be maintained in rivers.

If they are to be effective, such strategies must be organised for each catchment area and ensure that all the actors are involved in establishing economic development and environmental protection objectives. Basin authorities have been set up for this purpose in many countries (Valley Authorities, Water Agencies, etc.).

Transparency of information

As has been noted, it is improved irrigation efficiency that can be expected to contribute most to progress in future.

This means technical improvements, but depends first of all on more efficient management of available water resources. Many countries have accordingly adjusted their research programmes and are developing agrometeorological warning systems.

The awareness of irrigators can also be heightened by placing greater emphasis on the impact of irrigation compared with other uses of water. Irrigation is too often seen as a “natural” use of water, whereas it has serious induced effects. It is only by taking into account all the issues involved in comprehensive water management that progress will be possible.

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Annex Table 1. Freshwater abstractions by source

	Per capita m ³ /hab per year	Exploitation indices (%)	Total abstractions				Surface water				Groundwater			
			(million m ³)				(million m ³)				(million m ³)			
			1980	1985	1990	1995	1980	1985	1990	1995	1980	1985	1990	1995
Canada	1 604	1.6	37 594	42 383	45 096	..	36 733	41 486	44 059	..	861	897	1 037	..
Mexico	777	14.5	56 000	..	..	73 674	39 370	..	..	48 574	16 630	23 500	24 453	25 100
USA	1 875	18.9	517 720	467 335	468 620	..	402 750	366 095	358 790	..	114 970	101 240	109 830	..
Japan	724	20.8	88 200	88 495	90 083	90 497	75 450	75 150	76 561	76 922	12 750	13 345	13 522	13 575
Korea	533	..	17 510	18 580	20 600	23 700	..	..	..	21 222	..	..	..	2 478
Australia	844	4.3	10 900	14 600	..	15 055	..	12 360	..	..	..	2 240	..	..
New Zealand	575	0.6	1 200	1 900	..	2 000	..	..	..	..	..	..	..	..
Austria	282	2.7	2 190	2 120	2 360	2 250	1 055	1 005	930	870	1 135	1 115	1 430	1 380
Belgium	..	..	9 030	..	..	..	8 251	..	..	..	778	..	..	..
Czech Republic	244	15.8	3 365	3 440	3 396	2 520	2 820	2 873	2 787	2 024	545	567	609	..
Denmark	170	14.8	1 205	..	1 173	887	120	..	..	..	1 085	..	1 173	887
Finland	479	2.2	3 700	4 000	2 347	2 437	3 510	3 680	2 087	2 193	190	320	240	244
France	702	21.3	35 104	34 898	38 287	40 641	29 400	28 725	32 170	34 645	5 704	6 173	6 117	5 996
Germany	579	26.0	42 206	41 216	46 272	..	35 344	34 225	39 180	..	6 862	6 991	7 092	..
Greece	*699	*25.0	5 040	..	..	*7 030	3 470	..	..	..	1 570	..	..	..
Hungary	610	5.2	4 805	6 267	6 263	6 259	3 551	4 880	5 236	5 272	1 254	1 386	1 027	987
Iceland	614	0.1	100	103	164	164	5	8	14	14	95	95	150	150
Ireland	329	2.3	1 070	..	..	1 176	945	..	..	951	125	..	..	225
Italy	992	32.2	56 200	52 000	56 200	..	..	40 000	..	..	..	12 000	..	..
Luxembourg	137	3.4	..	67	59	57	..	22	32	28	..	45	27	29
Netherlands	518	8.6	9 197	9 302	7 806	..	8 190	8 231	6 757	..	1 007	1 071	1 049	..
Norway	..	..	..	2 025	..	..	..	1 620	..	..	..	405	..	..
Poland	313	19.2	14 184	15 453	14 248	12 066	11 899	13 076	11 928	10 078	2 285	2 377	2 320	1 988
Portugal	735	10.1	..	..	7 288	..	..	..	4 233	..	..	..	3 065	..
Spain	849	28.7	39 920	46 250	36 900	33 288	34 800	40 840	31 400	27 880	5 120	5 410	5 500	5 408
Sweden	309	1.5	4 106	2 970	2 968	2 725	3 511	2 348	2 360	2 084	595	622	608	641
Switzerland	369	4.9	2 589	2 646	2 665	2 595	1 667	1 693	1 724	1 693	922	953	941	902
Turkey	569	15.0	16 200	19 400	32 200	35 100	11 800	14 100	25 600	27 500	4 400	5 300	6 600	7 600
United Kingdom	228	..	14 496	12 947	14 237	11 752	12 006	10 426	11 528	9 279	2 490	2 521	2 709	2 473
Slovak Republic	264	1.7	2 232	2 061	2 116	1 406	1 575	1 390	1 388	801	657	671	728	605
North America	1 520	10.0	611 300	572 000	581 700	587 400	..	..	..	..	..	..	..	..
OECD/Europe	580	15.0	272 900	280 500	295 100	290 500	..	..	..	..	..	..	..	..
EU — 15	620	21.0	229 600	231 200	238 200	229 600	..	..	..	..	..	..	..	..
OECD	930	11.0	1 002 000	976 100	1 004 000	1 009 200	..	..	..	..	..	..	..	..

Source: OECD data supplemented by Blue Plan data (*).

Annex Table 2. Freshwater abstractions by major use (percentage)

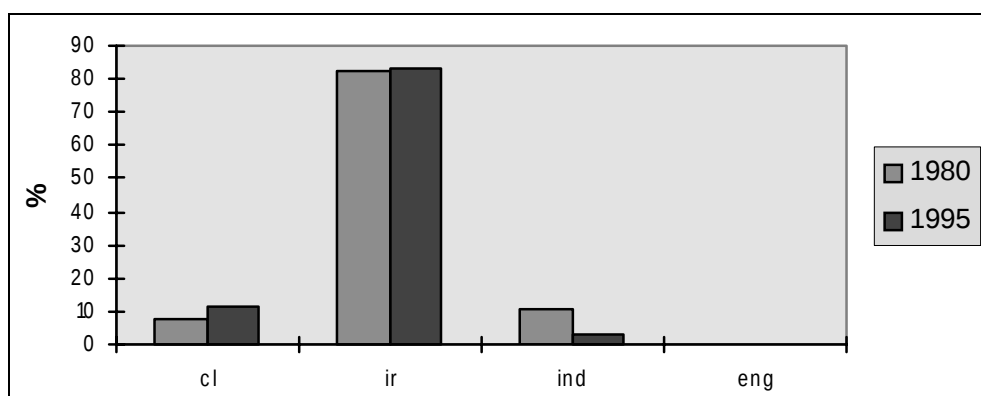
	Public Water Supply				Irrigation				Industry no cooling				Electrical cooling			
	1980	1985	1990	1995	1980	1985	1990	1995	1980	1985	1990	1995	1980	1985	1990	1995
Canada	11.3	11.1	11.3	..	7.4	7.0	7.1	..	8.6	8.9	7.9	..	39.9	56.9	59.7	..
Mexico	7.5	..	..	11.5	82.1	..	..	83.1	10.4	..	..	3.4	0.1	..	..	0.2
USA	9.1	10.8	11.4	..	38.7	40.5	40.2	..	10.4	6.6	5.7	..	40.4	38.7	38.6	..
Japan	14.8	16.3	17.6	18.0	65.3	65.5	64.5	64.2	18.7	17.6	17.3	17.2	..	..	..	..
Korea	10.9	14.8	21.8	26.2	80.5	76.4	68.4	62.9	8.6	8.8	9.7	11.0	..	..	..	..
Australia	..	12.3	..	..	74.3	69.9	..	..	..	5.5	..	..	..	..	..	..
New Zealand	..	..	..	9.2	..	..	..	55.0	..	..	..	13.0	..	..	..	..
Austria	22.8	24.8	33.3	31.0	2.3	2.6	8.5	8.9	25.1	23.6	20.7	21.3	47.9	47.2	37.4	38.7
Belgium	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Czech Republic	30.1	34.3	37.4	39.2	1.2	1.5	2.9	1.2	30.6	28.5	26.2	24.0	36.2	33.4	31.3	33.2
Denmark	39.8	..	40.9	53.0	..	..	25.6	15.8	22.0	..	19.2	9.0	..	..	..	..
Finland	10.5	10.2	18.1	17.2	..	0.5	0.9	..	..	..	69.0	66.4	..	..	10.6	15.4
France	15.5	16.9	15.9	14.6	12.5	12.8	12.9	12.1	15.8	14.6	11.1	9.7	56.3	55.6	60.2	63.5
Germany	12.0	12.4	14.1	..	..	..	..	..	6.8	5.8	23.7	..	60.4	62.0	62.2	..
Greece	12.2	..	..	..	82.5	..	..	..	2.7	..	..	..	1.8	..	..	..
Hungary	16.7	14.8	16.0	13.5	7.0	4.6	8.5	4.6	2.2	1.4	1.0	1.3	49.7	60.0	62.5	68.7
Iceland	84.0	84.5	50.0	50.0	0.0	0.0	0.0	0.0	10.0	9.7	6.1	6.1	0.0	0.0	0.0	0.0
Ireland	34.0	..	..	40.0	12.1	..	..	15.2	23.4	..	..	21.3	25.9	..	..	..
Italy	14.2	..	14.1	..	57.3	..	..	..	14.2	..	..	..	12.5	..	..	..
Luxembourg	..	..	95.0	58.9	..	..	0.3	0.4	..	..	4.7	24.5	..	..	-	..
Netherlands	11.2	11.9	16.4	..	..	..	..	..	1.9	2.0	2.5	..	65.4	70.4	65.9	..
Norway	..	26.6	..	..	..	3.4	..	..	..	68.1	..	..	..	..	..	..
Poland	19.2	18.9	21.1	20.4	2.0	3.4	3.3	1.7	12.9	10.6	9.7	6.8	50.7	53.1	51.2	57.3
Portugal	..	..	7.9	..	..	..	52.6	..	..	..	3.3	..	..	..	36.8	..
Spain	11.8	11.6	11.9	12.9	65.7	65.7	64.2	72.4	..	..	..	5.6	22.5	22.7	12.2	9.0
Sweden	23.3	32.8	32.9	35.0	1.6	3.2	3.2	3.9	43.3	37.4	37.5	27.7	..	0.9	0.9	2.5
Switzerland	42.6	43.2	43.6	42.1	..	..	..	..	..	..	..	..	57.4	56.8	56.4	57.9
Turkey	..	14.4	14.2	14.2	..	73.7	53.9	69.3	..	11.9	7.6	10.0	..	..	..	..
United Kingdom	40.8	47.1	47.0	52.0	0.6	0.6	1.3	1.2	12.9	8.1	6.2	4.3	26.1	19.2	16.9	2.2
Slovak Republic	..	28.3	30.4	39.2	..	5.9	12.6	7.9	..	63.7	53.5	49.6	..	..	..	..

Source: OECD.

Water use: national examples

In Mexico, irrigation accounts for 80 per cent of abstractions (Annex Figure 1). Domestic requirements have increased greatly with urbanisation and are competing with agriculture.

Annex Figure 1. Abstractions Mexico

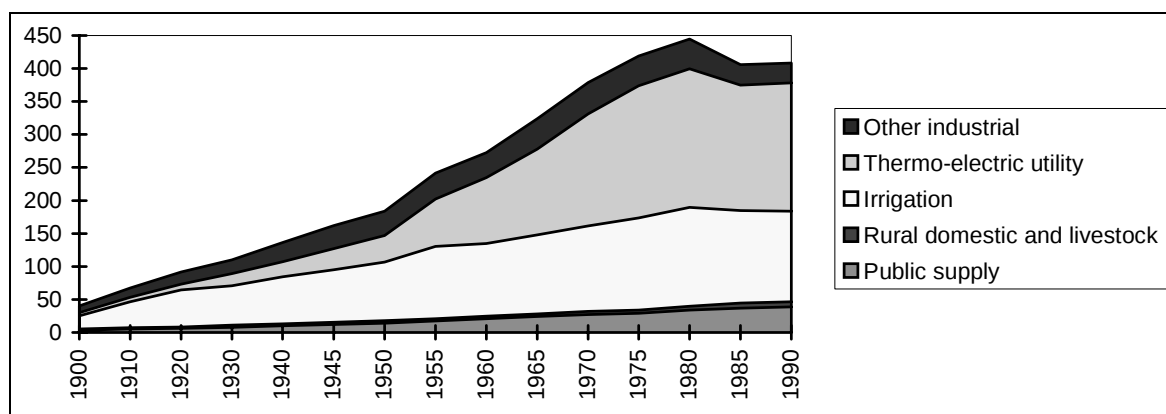


ind: industry, ir: irrigation, cl: local authorities, eng: energy.

Source: OECD.

In the United States, irrigation and energy needs together account for the bulk of water use, though recently the requirements of these two sectors have declined (Annex Figure 2). Domestic requirements have doubled since 1960, reflecting growing urbanisation and a 40 per cent increase in the population. The United States has the highest per capita abstraction rate in the OECD area. Basin irrigation systems, which consume a lot of water, were mainly used until the mid-1970s because of the low prices charged and abundant water resources.

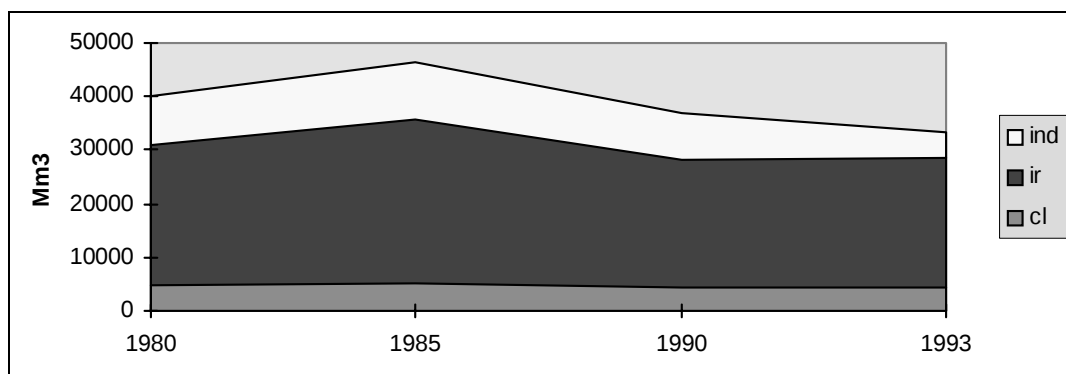
Annex Figure 2. Water use by sector in the United States
(billion of gallons per day)



Source: U.S. Department of Commerce and U.S. Department of Interior quoted in *The Council of Environmental Quality*, 1997.

In Spain, the pressures on water resources are among the most intense in the OECD area. Irrigation is vital to Spanish agriculture (16 per cent of farmland accounts for 66 per cent of agricultural output); it accounts for almost 80 per cent of total water use (Annex Figure 3). The development of tourism in the South is generating new needs. A series of droughts in the late 1990s obliged Spain to limit the use of water in urban and rural areas. A long-term project under consideration would involve the transfer of water from France (from the Rhône) to meet the country's needs.

Annex Figure 3. Trend in abstractions in Spain

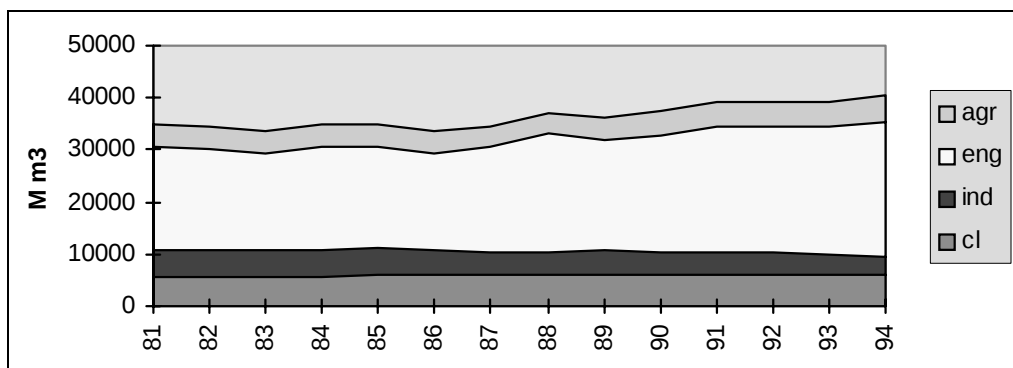


ind: industry, ir: irrigation, cl: local authorities.

Source: OECD.

In France industrial abstractions have been declining since the start of the 1980s, while abstractions by local authorities rose by 15 per cent from 1980 to 1995 but have been stable since 1989 (Annex Figure 4). Energy (nuclear power plants) accounts for the largest volume of abstractions. Irrigation needs, which vary greatly with climatic conditions during the year, have risen over the long term. Irrigation is gradually coming to account for the largest share in terms of consumption (Annex Figure 5). This development is particularly marked in the southern half of the country, where irrigation activity is concentrated.

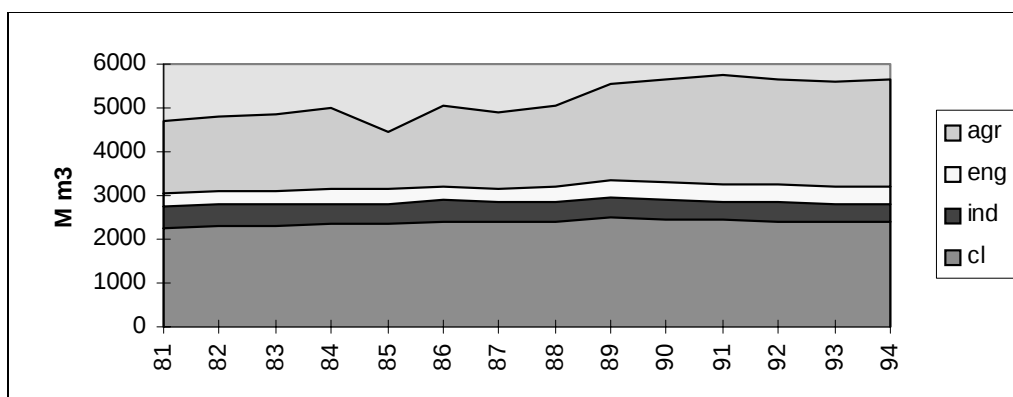
Annex Figure 4. Water withdrawals, France



agr: irrigation, eng: energy, ind: industry, cl: local authorities.

Source: French Ministry of the Environment.

Annex Figure 5. Water consumption, France



agr: irrigation, eng: energy, ind: industry, cl: local authorities.

Source: French Ministry of the Environment.

SOME PRACTICAL PERSPECTIVES ON WATER PRICING REFORM FROM AN AGRICULTURAL VIEWPOINT

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1. Background

This paper is intended to review the role of water pricing in the overall context of water reform in Australia, but it comes from a limited, rural perspective. As such, it will touch on the other major reform strands in an integrated water policy package. However, the paper will focus on the implementation, impact and interaction of pricing policy on those elements, and vice versa.

Australia is the driest continent, so efficient and effective use of this scarce resource is a key national priority. The water reform experience in Australia over the past 10 years or so has encompassed four major strands in relation to water issues:

- pricing reform, including detailed attention to asset performance and standards;
- property rights and obligations, and the establishment of a trading system;
- the role of institutional reform, which is only partially complete;
- environmental outcomes and effects of water use on quality as well as quantity.

Each performs a partial role in promoting the efficiency and effectiveness of both the water businesses (the service deliverers), the environment, and the ultimate users of the resource, a term which includes rural use (as an input to the productive processes on farm), domestic use, primarily in relation to urban areas, and for industrial applications (which may be either urban based, such as heavy manufacturing process like car making, or rural processing, such as milk and cheese factories or wool scouring).

The scope is limited to the Australian experience, and is practical in orientation rather than being a theoretical exercise. It will draw on case study material, and the different experiences in implementation and approach between the States within a Federal system of Government.

2. Why do it? The need for reform, the drivers and the main policy responses over the past 10 years

Until the 1980's, water issues were primarily oriented towards drought-proofing Australia's cities and rural irrigation areas. The last major dam building exercises took place at about this time, prompted in part by a very severe drought which exposed all parts of the nation to water shortages.

This led to some questioning of dam building by certain economists, rather than having everyone simply accepting the emotional, and financially very real, reactions to an extreme position, as had happened in the past. Rural water users had always been a large drain on the public purse across the country, and questions were asked about the sense of throwing good money after bad.

To put this in context, most of the water matters in Australia are determined at a regional, or State, level. In the State of Victoria, a reformist Government took the economist's view of pricing for Government owned enterprises. This was not wholly a good thing for a number of reasons outside the scope of this paper, but one of the upshots was that the question was asked "if urban water utilities have to bear the full cost of service provision, why shouldn't rural services be in the same position?" Victoria became the leader in the push to reforming not only water, including rural water services, but other utility services.

At that time, rural water services were provided by a statutory authority which behaved as a Government Department. Its revenues reverted to the Consolidated Fund, and its expenditures were determined by Budget appropriation. Its pricing was determined by submission to Cabinet.

This was, of course, not the only aspect of Government control over agricultural performance. Marketing arrangements in particular, extension activity, and overall interference in agriculture led to a strong ethos of "bush socialism", which could be summarised in the well known saying that "Australia rode on the sheep's back". The outworking of this was a strongly held view in rural areas that the rest of the country owed agriculture a living, that subsidies were a good thing (unless they were for anyone else), and that water, being God's gift, should be delivered free. As with a number of other countries, elections were times when politicians could "feel a dam coming on". That spirit is not necessarily dead in the bush.

As a result, cheap water, environmental degradation as agriculture spread without heed of cost (either financial or environmental), inefficient service from an organisation where revenues and costs were totally unrelated, and a retarded agricultural sector hiding behind a subsidy wall were only to be expected.

This mixture has all the ingredients for an explosion in a reform context, but eventually a deal was struck between the farmers, the Rural Water Commission (RWC, as the organisation was at that time) and the Government. The essence of the deal was that the Government would continue to support the RWC, albeit on a reducing scale, that the RWC's organisation would make efficiency gains each year, and that the farmers would contribute by committing to real price rises. One of the unfortunate aspects of this is that the pricing system recommended by the Government was based on current cost accounting, allowing for a positive real rate of return on Government funds invested in the business's assets. Farmers did not understand this and regarded it as accounting trickery to put the price up.

This deal seemed all very well, except that the dairy industry (the main water users) experienced a severe price downturn at the same time. Life gets tough when your customers go on strike. Cows were chained to the front gate of the RWC in Melbourne, water payments were withheld, and the

whole thing degenerated into a farce. Another unhelpful aspect of the background was that Victoria was the most advanced state in terms of water pricing — there was a mixed bag of other approaches in the other states. Victorian producers, although paying nothing like the full cost of delivery, believed they were subsidising all the other irrigators in the country, who were paying even less!

The Government wrested back control by appointing a Committee to investigate future options for the RWC. It was chaired by a respected former opposition (country, and conservative) parliamentarian, who recommended that the current cost based system be scrapped, and that the RWC be broken up into regionally based authorities.

It is the resultant change, commencing in 1992, to renewals based pricing, rather than depreciation based pricing (either on a historic cost basis or on current cost), that has provided the springboard for a substantial change in Victoria and has driven the national reform agenda.

It is from this history of strife that a general consensus on reform has been brokered between State governments in Australia and rural water users, with the environment being a late comer to the fold, and not without further difficulty.

3. Next — the major reform influencers

The Council of Australian Governments

In addition to this State based activity, another reformist Government at Federal level co-ordinated an approach with the various States to review water administration from the sustainable resource management perspective. This created a framework for “full economic cost recovery” as the basis for effective water management under the powers of the Council of Australian Governments (COAG), which comprises the heads of each Australian State and Territory, plus the Federal Government (see Appendix).

At the same time that this was being implemented by COAG, by the same people, at the same place, at the same time, another Report with far-reaching consequences was also published; the Hilmer Report into competition policy. This report provided the framework for re-engineering the Australian economy as a whole in a more competitive and market exposed environment, one where businesses could not, by dint only of Government ownership, expect or receive taxation benefits or any other favoured treatment, among other things.

Both of these reports provided a huge impetus to effective water management, for both rural and urban areas. The framework definitions of full economic cost recovery did not include the competitive neutrality consequences of the competition reforms. The COAG framework report in fact preceded the competition policy report — it is just that they were completed together.

Competitive neutrality is a key part of the reform process advocated in the competition policy report. This means that, in general, government businesses at State or Federal level (including water) will be treated independent of ownership, i.e. as any other private sector business. This exposes them to taxation (or taxation equivalent payments) if they are making a profit. This profit may occur if they are subject to the COAG guidelines and exercise due diligence in relation to asset renewal, as either the depreciation based on “deprivals valuation”, or “renewals”, is likely to be substantially in excess of historic cost based depreciation. And this is not to mention any externalities or opportunity cost which may be included!

Thus by the introduction of good economic principles, the potential exists for substantial price rises in water which are not related to the realised actual costs of harvesting crops and delivery of the water resource.

It is only now, with the full effects of all policy changes being seen and the road testing of cumulative policies having taken place, that industry (including farmers) is beginning to appreciate that the conjunctive outcome could be a 35 per cent to 50 per cent price rise, not related to the actual costs of water delivery and storage, but to external effects such as tax. We await the next episode with interest.

The Murray Darling Basin Commission

Australia is a large country which apart from the coast is sparsely settled. The Murray Darling Basin is one seventh of the landmass, and represents most of the non-coastal human activity on the continent. Many of the reform issues are only relevant in the context of the Basin, such as, interstate water trade.

The Murray Darling Basin Commission (MDBC) has had three customers for water services in the past (South Australia, New South Wales and Victoria), and more recently Queensland has become the fourth (on a relatively restricted range of issues). It also has substantial natural resource management functions.

Its cost sharing for water services (one-third each for recurrent expenditure, and the Commonwealth contributing to capital funding to make it one quarter each on the capital side) is not related to services delivered in relation to commercial water activities.

Over the past two years, moves have been put in place to make costs transparent and relevant to the services delivered. This is still to be finalised, but will give the common currency needed for interstate water trading in the future. This should overcome some of the messiness in the current pilot permanent trading arrangements being instituted in the lower Basin (see the discussion below), and should lead to common methodologies across the participating states. It would be difficult to see one set of pricing principles for MDBC based catchments in each State and different principles for others. The MDBC reforms to pricing are taking careful account of the COAG and competition policy reform principles.

Again, the magnitude of the change, with the renewal of the system explicitly recognised rather than cash-funded each year by the Governments concerned, plus the impact of tax equivalent payments, is substantial.

At the same time that this pricing reform was underway, and somewhat related to it, there was a concerted move by the Murray Darling Basin States to advance on a number of fronts, with a common or at least harmonised system of property rights and, as an extension, interstate trade being an envisaged and intended outcome.

In the beginning (around the early 90s), this was driven by the engineers and hydrologists, who worried about losses, exchange rates and wild tributary inflow. Some heretics from the economic side made life tough by reminding people that pricing also had something to do with it. Since then, the distortion cost of existing pricing differences (pre COAG) between adjoining States has been calculated by modelling the introduction of trade in a system with embedded pricing differences. In

the lower Murray Darling Basin, some A\$ 10 million (US\$7.4 million) per year has been estimated as the revenue foregone to efficient agriculture in favour of less economically effective enterprises.

The inconsistent and distortionary effects of resource input subsidies applied arbitrarily (say by jurisdictional boundaries) can only make more efficient farmers less productive for questionable benefit to the less efficient. As Australian water economic studies show, you could give water to some irrigation farmers, and they would still unviable.

Physical problems are relatively easy compared with trying to harmonise pricing systems across competing sovereign states (the EU countries may be familiar with this). And, as is also usual, the pace of change is slow.

4. So what is it? What does full cost recovery mean anyway?

If it were only as simple as saying, “Yes, of course, our policy is for full economic cost recovery, and this will be applied in a competitively neutral fashion in the water sector, without any distinction between enterprises providing services in the private sector or in Government ownership, and all externalities are fully known and priced to all parties.”

In practice, it has proved difficult to actually define some of these costs or to even capture their magnitude in the first instance. Any other country undertaking such an exercise will likely find (or has found) the same difficulties. This is not for want of good intent, it’s just that it’s hard.

As a result, another series of exercises has been undertaken at national level to try to actually understand what this means. The COAG policy statements are attached as an appendix, to show the scope of the policy framework that the implementers were working with.

Because each State has its own administrative arrangements, there is a diversity of delivery arrangements, and there is no one central repository of even financial information. The States agreed to look at cost recovery at the level of a funds statement, (who spends what), to try to cover what this really means, because of this variety of enterprises, public (of various sorts) and private, which undertake a range of activities, and also because some activities remain unfunded, i.e. not done or fixed at all.

This is where pricing comes into contact with institutional reform, and the nature of the organisation which is undertaking any activity. If the object of the reform is to establish the reasonable interpretation of conditions so that a single water economy can be instituted in a Federation of States, quite a lot of it does matter.

What the implementation group ended up doing was to try to work out the sources of funds, being Consolidated Fund (i.e. paid for by Government), not the Consolidated Fund (i.e. paid for by somebody else), and unfunded (if it is possible to work this out at all). This gives some chance of identifying which parts are actually paid for by water users, rather than by subsidy or cross subsidy by Government. It certainly aids in accelerating a view of what transparent costing means.

A few examples:

1. A Government Department undertakes all water activities. How can this be divided up to discrete catchments, if that is the relevant unit, if accounts are kept at entity level, all cash based? How can you apply this in a catchment without some very gross apportionment's? What do you mean by investment and capital? Opportunity cost? The weighted average cost of capital? What about tax? What is an asset register anyway? This is meaningless in this context of Government Departments.
2. A Statutory Authority undertakes water distribution activities. At least, accounts are on an accrual base, and there is some separation of capital from recurrent expenditure. They have an asset register, but in general, tax or tax equivalents and economic measures such as opportunity cost are a foreign language. They usually have an obligation to do some resource management works beyond water activities only.
3. A local municipality is responsible for maintaining local roads in an irrigation area. Rising water tables lead to premature road decay. How is this dealt with in the context of "full economic cost recovery"?
4. A river bed continues to become more degraded. Salinity worsens, and very expensive steps are identified to control it, but no funds are committed. Blue green algae infest lower level lakes. How can this be taken into account? Should it be?
5. Irrigators form a private company to do their internal water distribution rather than continuing under Government control. They are subject to the Tax Act and Corporations Law. This is strictly financial rather than economic. Does this matter?

5. Transparency of costs and subsidies

In February 1994, COAG agreed that all water services across the country should reach full cost recovery. The prices set to achieve the recovery of the full economic costs of water services must be transparent, in that each user must be able to have a clear understanding of what services s/he is paying for, and must be able to see clearly any cross subsidies a given government may choose to permit.

This exercise is also being undertaken in the context of institutional reform in line with achieving a separation of regulator from operator and resource manager, and also from the viewpoint of uncoupling where practicable the local distribution systems from the monopoly service provision of headworks and ancillary services. As such, it is anticipated that change will also occur in the magnitude of the costs as better, or more clearly accountable costs are refined under the new management arrangements.

It is necessary also to ensure that only those costs truly attributable to any activity are actually included, and also that all costs are actually fully allocated. The users' share is the proportion of the water costs that should be recovered from users, as opposed to the portion that the wider community, through the government, should bear. In effect, this is the explicit statement of Community Service Obligations required under the COAG arrangements.

Community service obligations

COAG's transparency requirement has two aspects. First, users should be aware of what services they are paying for and how they are charged for those services. Second, *"where full costs are subsidised by a jurisdiction or local government authority, any such subsidy or any community service obligation [should] be made explicit and transparent"*. This means that, if a government chooses to subsidise a particular user group (for example, pensioners or farmers in drought-declared areas), then the government must make it explicit that it is subsidising that user group. Transparency means that users know exactly what they are paying for, so they can be sure they are only paying for services that benefit them.

A question arises as to the real meaning of either subsidy or cross subsidy in this context. From economic theory, it is possible to have a wide range of outcomes all of which could come from legitimate pricing principles. These cost outcomes may range from the extremes of short run marginal cost to full bypass price, which would not even accept the writing-down of asset values for years of service. In other words, appropriate pricing outcomes may extend over orders of magnitude, depending on the actual definitions used.

A Community Service Obligations is also a flexible concept. In many areas, it is defined as the payment for the provision of a service by Government which an organisation would not undertake for its own commercial reasons. This is a good starting point, but it fails to take account of the specification of conditions for doing business which any Government may impose as a licence condition for any water entity (or any other entity for that matter). The breadth of interpretation of this is limited only by the number of Governments involved. The difference between a CSO and a subsidy can be a very fine and subjectively drawn line.

It is relevant to note that this is closely related to the institutional reform agenda (refer Section 6), where separation of service delivery from regulation and resource management is a primary tool to promote clarification. Some Governments have internalised a number of externalities by use of licence conditions, but the clear separation of Government Departments from water delivery is patchy and untidy overall. Nevertheless, this process is occurring across jurisdictions, and has shown good outcomes as well as great potential for clearing the view.

In addition, it may also be that it is not fair to charge users for the full economic costs of all water activities. It may be fair only to charge them a certain proportion of those costs, as they may not be the only beneficiaries. COAG provides guidance for determining which activities should be included in costs to be recovered from users:

- “The full cost of all water services attributed to specific identifiable beneficiaries or impactors [should] be recovered by way of charges on them commensurate with the level of services provided in generating the benefit or required to manage/offset the impact of their activities.”

Example 1: The costs of services to deliver water supplies to users from the major rural dams should be met by all those who benefit in proportion to the water they use — the user pays approach. Users could include major urban corporations, irrigation companies, local government water supply authorities, individual landholders, and industry.

Example 2: the costs of services to manage declining water quality should be borne by all those contributing to that decline commensurate with the effect of their polluting activities — the polluter pays principle.

- “The costs of public benefits/impacts management which are unable to be attributed and charged to specific beneficiaries/impactors should be treated as community service obligations.”

For example, the costs of services that benefit the community generally rather than specific individuals — which may include, for example, maintaining some recreational opportunities, long term planning etc. — should continue to be met by Government (CSO).

This beneficiary/impactor pays principle is also spelled out by:

The cost of water services should be paid by those who are responsible for causing, or benefit from, those services. Those who cause more services to be required, or benefit more, should pay more.

The process associated with establishing “correct” proportions of costs to be attributed has resulted in major exercises in at least one case, New South Wales, where an Independent Pricing and Regulatory Tribunal (IPART) has devoted a lot of time to the better understanding of these matters amongst irrigators. They are seeking explicit agreements as to the proportion of any resource management cost which may be apportioned to users (and the corollary of the proportion to be picked up by the Consolidated Fund — perhaps through another Government Department, such as Sport and Recreation).

IPART has been involved in the regulation of bulk water prices, and has been especially involved in the resource management charges proposed by the relevant government department. It has established five pricing principles which form the basis of its pricing decisions:

1. Water charges should be based on the most efficient way of providing water services.
2. The Department’s administration of water resources should achieve financial stability and deliver a sustainable level of water services.
3. Pricing policy should encourage the best overall outcome for the community from the use of water and other resources to store, manage and deliver water.
4. The cost of water services should be paid by those who are responsible for causing, or benefit from, those services. Those who demand more services, or benefit more, should pay more.
5. Pricing policy should promote ecologically sustainable use of water and the resources to store, manage and deliver water.

In NSW, the cost of providing rural bulk water services has not traditionally been the main basis for the charges levied on water users. This is the case not just in NSW, but across Australia as a whole.

In addition, when the costs of service delivery have been factored into the charges to be paid by water users, only the ‘accounting’ costs of water service delivery have been taken into account in the past, not the full ‘economic’ costs.

Case Study 1. The Torrumbarry Weir

In 1992, a major diversion weir on the Murray River sprung a leak. This was not just a small incident, but the major failure of a structure which diverts 800 000 Ml of water each year, involving some 1 400 farms and their associated communities.

Instead of allowing the engineering fraternity free rein to make good the damage, the Murray Darling Basin Commission decided to look at the fundamental economics associated with replacing the structure, and put in place a repair operation in the short run (which lasted a year). The study was undertaken by ABARE (Australian Bureau of Agriculture and Resource Economics).

The region concerned was a patchwork quilt of the good, the bad and the downright ugly features of Australian irrigated agriculture. It had very good dairy areas, highly productive and fertile horticulture zones and some heavily salinised country which contributed substantially to the most saline point source of pollution along the Murray River, Barr Creek.

After a year of modelling with water prices set to full cost recovery (which was not too far from the reality in that area), the full cost of salinity attributed properly to the region, and farmers’ labour valued at the opportunity cost of off farm work for other farmers, the region as a whole was slightly below break even. The speed of structural adjustment (out for the saline areas, in for dairying) relied on water trading and the pace of farm reinvestment decisions. This was the key determinant in the plus-or-minus outcome from the economic evaluation.

One seemingly perverse result took place from the modelling, which seems to be holding true in the “real world”. That is, that with increasing water prices (obviously within a range), better agricultural outcomes in terms of profitability and better environmental outcomes was the result. In other words, water resources dedicated to poorer farming practices was sold and purchased by the more profitable farmers. It is also true that environmental outcomes have always been synchronous with farming outcomes — poor land having less potential to generate good agricultural outcomes, so its retirement relieving a salt load from the system.

In a nutshell, the bottom end of farming (where even if they are given water free, they will still not make a profit) owns and uses the water resource, pollutes the environment and drags down the better agricultural outcomes.

The water resource is unavailable, or at least a constraint, at a more profitable end. More profitable agriculture results from farmers thinking about their resource use, and then having enough cash to translate this into action. As the price of water goes up, unprofitable farmers tend to go out quicker or change to more profitable farming if they can, waste of resource goes down as it is valued more highly, environmental outcomes are enhanced by farmers being more alert to the potential for re-use (and having the cash to finance it).

Thus correct water pricing, together with a market based system of water trading, results in improved agriculture as the less profitable side of farming is restructured by market forces, and resource migrates to more profitable enterprises where, usually, the quality of management is higher. The price signal is the driver for farmers to take decisions. This is what encourages better farm management.

The Torrumbarry Weir was replaced, in spite of the (very slight) negative economic assessment. The primary beneficiary could easily have been the Federal Government, which may have faced a large bill for unemployment benefits otherwise. There are not too many jobs available for unemployed farmers aged 55, who left school at 14 and have never done anything else. Structural adjustment was encouraged by the creation of a Development Organisation, to look at other regional opportunities for change, and water trading, always reasonably brisk in the area, was further encouraged by promoting soil salinity surveys and farm capability planning.

Case Study 2. Murray Irrigation Limited (MIL)

In New South Wales, institutional reform has led to the ownership of the irrigation distribution system to communities of farmers. These privately owned companies formed by the farmers owning the water rights are not necessarily small (MIL accesses 1.5 million Ml of water each year). They hold licences to divert the water and operate works, plus obligations to reduce pollution from drainage water and residues.

This institutional reform gives farmers a more effective voice in the management of the system, leading to increased scrutiny of investment decisions and cost containment. It also encourages farmers to think seriously about other factors in their decision-making rather than simply cost.

What has been found is that farmers' first concern is the price of water at the wheel, but when farmers are confident that they are not being charged too much, the service delivery issues and water quality issues come to the fore. In Victoria, South Australia and New South Wales, there is a move by farmers to increase water prices in recognition of these very factors.

While it may be thought that areas with lower environmental standards (and costs) should be attractive, in fact this is not the case. To the extent that farming resources are flexible, the migration of both farming and traded water is to the areas with higher standards and costs.

Environmental costs have been internalised to a large extent through the licensing system for MIL, with compliance to a contractual Land and Water Management Plan between the Government and MIL being the cornerstone of the deal. This gives effect to better environmental outcomes, continued contributions from the Government in recognition of the state of the works transferred, and a view by MIL that leading the debate and getting win-win outcomes is preferable to being punished financially for poor environmental performance.

The costs of doing business for this irrigation delivery company have improved significantly since the district became customer-owned. Staff numbers were cut — to 38 from about 100, while significant investment took place in automating large parts of the system and transforming methods of billing and ordering.

The New South Wales Government is continuing to contribute to asset refurbishment in recognition of the poor state of the assets being transferred to the Company. This contribution of funds is regarded as income by the Australian Taxation Office, and is subject to company tax — in effect a shift from the coffers of the State Government to the Federal Government. It would be better if tax policy and agricultural policy were better aligned, but the competitively neutral world post-Hilmer makes this very difficult.

It is difficult to see that the Australian Taxation Office will take too sympathetic a line in relation to State Government owned irrigation distribution businesses under these circumstances, and, with the policy setting for full cost recovery being based on a concept giving greater than historical cost depreciation to ensure system survival, some further work needs to be done. It has been mentioned that the logic of the position is to debt fund everything. If this happens, it will not be too long before we could have a series of broke irrigation companies — the same position which led to the Government being involved in this in the first place — about 100 years ago.

The role of economic regulation comes to the fore in those circumstances to ensure that the correct provisions are made, which are adequate in the long run to sustain the business. If this happens, the cycle can be broken. The independence of the regulator — being strong enough in the licensing context and far enough away from Government to avoid its inherently interfering tendency when markets are poor — is quite crucial. This is the step which is different from the past, and it is also one of the key lessons from the privatisation experience internationally. The outcome will be good if there is a good regulatory environment, and if not, the result may be at worst failure or at best suboptimal.

Having determined the aim of the pricing process (full cost recovery of full economic costs and transparency of process), and determined the principles for ascertaining the relevant costs (beneficiary/impactor pays), IPART then examines the rural bulk water sector activities of the Department, and the costs associated with that sector, as well as the district-specific costs, the appropriate apportionment of costs between direct water users and others, and determines an appropriate pricing path and determination for the forthcoming period.

6. The significance of pricing to other reforms

Property rights and trading

Permanent trading in water entitlements is a market driven implementation of structural adjustment. It allows more profitable and efficient water users to compensate the less efficient financially for freeing up the resource and allowing economic development to proceed.

Temporary trading is about making seasonal adjustments between right holders to account for short run positions, like being short of one watering for a cash crop, or being caught in a forward commitment of commodity, as well as other individual farm yield based reasons. It is not about long run positions.

These are two separate and quite different markets, and water price plays a different role in each.

In Australia's lower Murray Darling Basin, there are three sovereign States, each with their own pricing policies although, as described above, these are being brought together. As the area is supplied by the same set of headworks (in general), there is no physical reason why, again in general, temporary and permanent trade is not undertaken to maximise national agricultural outcomes.

In terms of *temporary* trade, the role of water pricing is obvious, not just in the price paid for a trade in its own right, but also in relation to the capacity to pay. An example: assuming there are two identical dairy farms with identical water consumption (say 500 Ml per year), one on one side of river, and the other on the opposite side. There are identical headworks, river systems and delivery mechanisms with identical costs. Because of the different methods of pricing in the two states, (say, no headworks charges in one), the other farmer pays A\$ 6 x 500 more each year for water for the same income. So he has A\$ 3 000 (US\$2 200) less capacity to buy any additional water from trading — in theory he will be outbid by the first farmer for any spare water in the system. This puts a relatively less efficient farmer on equal terms with a more efficient one in a competitive market.

This is not acceptable from a national policy viewpoint. Hence the concentration on equivalent pricing methodologies (which will, of course give different outcomes when actual costs are included). COAG is about equality of treatment for trade exposed areas, not about the same pricing outcome.

In terms of *permanent* trade, the annual water price at the farm gate is perhaps less distortionary. It would be one element, but only one, in deciding to buy permanent water and probably less significant than other factors such as land capability, access to markets and access to the resource itself in terms of long run security of supply. It also has an expectation built in that the States will move together where trading is a reality. It may also be more easily corrected than for temporary trade even if this were not to be the case, by transforming the differences into an annuity, but this assumes policy stability — which is a big assumption to make, to say the least.

There is a pilot project being established on the Murray River to allow the first ventures into permanent interstate trade. It is a constrained project, both in geography and methodology, and has defined as outside-the-bounds anything which can be difficult.

A common currency was needed to define full cost recovery in this project, as no State felt even mildly inclined to provide water buyers in any other State with anything which could remotely be regarded as assistance (or a subsidy), in fact quite the opposite. This common currency issue still has the flaws associated with different interpretations of the various elements of cost, and issues of jointness.

Hopefully, the outcome of the COAG processes will be the achievement of Australian irrigation taking a one-country view, but entrenched attitudes as well as legitimate differences in outlook between the States have still to be fully assimilated.

The fact that water trades at a substantial premium in both the temporary and permanent markets (up to A\$ 100 (US\$74) per Ml for temporary water in a year when resource is relatively tight like this year, and up to A\$ 650 (US\$478) per Ml for permanent water, and rising) puts some of the arguments into context about cost recovery. In the last season when resource was relatively tight, about 10 per cent of water traded in Victoria at about a A\$ 20 (US\$15) per Ml to A\$ 35 (US\$26) per Ml premium on average over close to full cost recovery.

Interestingly, the higher water users tend to be the best farmers in terms of productivity and ecological performance. Management expertise shows.

Institutional reform

Over the last decade or so, the policy environment in which the water industry operates has changed markedly. Not only is there a continued demand for water for consumption purposes, but there is also growing concern over the long-term sustainability of rural water.

This change has provided a particular challenge and a changing water agenda for both Governments and water users. Far greater interest is being directed to environmental and natural resource management to better deal with the effects of river regulation, water extraction, water use and effluent and drainage disposal. In addition to this, there is substantial pressure for further development in areas where the resource base is under less stress, and good agricultural opportunities exist.

The separation of service delivery from regulation and resource management has been the driver to distancing water distribution agencies from the Government Departments of which they were previously a part. This is still embryonic in some areas, with the separation being internal to the Department. It results in a clearer focus on the tasks at hand, with no second guessing as to Government intent, which is incorporated in licence conditions.

For rural areas, this separation has incorporated a substantial element of customer involvement in pricing, investment and standards of service. This holds whether the separation is within Government ownership (as in Victoria) or in customer ownership (as in New South Wales and South Australia). The first move in this is for cost reductions, as irrigators drive down the water price at the farm gate. It is likely to result in greater scrutiny of both activities and the means of providing services.

However, in reality, the services must be maintained in perpetuity (all other things being equal), so the move to pricing to capture the future renewal of the system is inevitable, and the tax consequences of this have to be addressed.

As such, the pricing consequences of applying full cost recovery principles are not likely to result in changes as substantial as appear on first examination while continuing as part of a Government Department. The long run security of the system appears to be as well catered for under the present model of community control, with some effective external price regulation, whether this means transfer of assets or not.

The regulatory framework appears to be critical, preventing the price of water falling below long run requirements for system stability. Over time, government departments have been notorious for inefficiencies and under-maintaining systems, at the same time as running a branch of the Employment Office. The potential for customer dominated boards to under-recover and “mine” the asset base means that embedded standards of asset maintenance behind water pricing need to be established by (preferable independent) regulation.

Customer service, again a difficult concept for government departments, becomes the credo of the newly created service delivery agencies when they are owned or controlled by their customers. The ability to cope with change is enhanced — a new watering regime to allow for different cropping (for instance the pressurisation of the system to allow overhead watering) is more easily financed if customers demand the service and are prepared to pay for the enhancement. This makes the capital side of the system customer responsive and very conscious of value for money.

Environmental consequences

The most difficult task associated with implementing the harmonised pricing regime foreseen by the COAG framework is not in fact the asset maintenance, valuation and consumption exercise, but, as usual, pricing the unpriced elements.

One of the more useful observations that has been made is that good economic outcomes and good environmental outcomes tend to go hand in hand. There are no permanent water transfers into areas which create an environmental hazard. This is the experience of Australia’s seven years permanent trading, even without all externalities being fully charged. If all externalities were properly costed and charged, this would be even more so, as water would migrate from degraded areas more quickly.

Good land with good management, with water well applied in a sustainable manner, produces the greatest longrun returns. It does not mine the environment, as long run agriculture is not about short run optimisation, especially in a trading environment. This is the real result of structural adjustment with fully transparent pricing and removal of subsidies.

When the MDBC’s Water Market Reform Working Group was looking at the permanent trade pilot project, one of the issues was how to evaluate some of these externality related costs. It came up with a fairly rough rule of thumb, which recognises that the science is probably inadequate, that the economics can’t cope readily with the valuation questions, and that the problems were real. Instead of simply blocking everything until they knew everything, they decided to *err in favour of the environment, or take the precautionary principle* — a position which recognises explicitly that the environment has an implicit value to the community, that it is positive and probably underestimated.

The evolution of this in relation to the permanent trade pilot project between the States was that if 100 Ml of water were to be traded to an area where transmission losses were greater, the 100 Ml would be reduced so the buyer would receive only say, 83 Ml, if that were the conservatively estimated loss. If the water were to move to an area where the losses were less, the number would not be increased — the maximum would still be 100 Ml for the buyer, with the environment benefiting to the extent of the change.

There are of course more rules than this — for example, some no-go areas where salinity consequences of development would be overwhelming (but, again, these areas are less desirable — the rules are just to make sure that it does not happen).

The pricing discussions have also brought fresh attention to some issues of property rights and the interaction with pricing. In general, water for the environment is free — a cost of doing business for the water agencies concerned. This is especially true of protection of instream values, and it is recognised that this may increase in the future as the scientific knowledge improves.

Another aspect of environmental water is the “consumptive component”. This is an explicit allocation for wetland watering, for example. This allocation should logically be tradeable for a variety of reasons: two of which are that:

- it is an extraction from flow; and
- more or less water may be needed in any season depending on the weather.

Logically it is a counter-cyclical user of the resource compared with irrigation. When it is dry and temporary tradeable water is expensive, wetlands should not be watered for ecological reasons. When it is wet and temporary tradeable water is cheap, wetlands should be full. As such, the environment can reasonably be an active trader and profit taker by judicious and ecologically sound resource use. This also provides a bank of environmental funds to undertake works or research (preferably on related matters if community politics are to be taken into account).

Given the “profitable” status of this water use, farmers do not feel too inclined to accommodate this within the cost-of-doing-business envelope. The deal brokered at this time is that these allocations will pay the costs of delivery (at marginal cost rates).

A number of environment related matters will have a far more profound effect on agriculture than water pricing, one example being the cap on Murray-Darling Basin diversions.

In June 1995 the Murray-Darling Ministerial Council published “*An Audit of Water Use in the Murray-Darling Basin*” which reported that water extractions from both regulated and unregulated streams had increased significantly in recent years and needed to be controlled to minimise further damage to the river system and to assist in protecting river health. Governments agreed to not issue any further river licences for irrigation on all unregulated streams in the Basin (some unregulated streams were already embargoed and all regulated streams were embargoed) and to limit development in the Basin to the 1993/94 level.

Interim caps on off-allocation diversions (that is extraction of uncontrolled flows, usually high tributary inflows, on regulated rivers below the dam) have been set or foreshadowed for each of the inland river systems. Arrangements to ensure that future diversions remain within the cap are being put in place.

This, plus more explicit recognition of the environmental needs of healthy rivers and the potential for issues concerning native title, is likely to swamp any effects of price changes by altering the volume of water available for consumptive uses.

The price at which water trades in the temporary or permanent marketplace will reflect this relative shortage in the future, as consumptive pricing policies are cost based rather than market based.

7. Lessons so far

Australia is firmly committed to achieving benefits to national productivity, agriculture and the environment from the reform of the water sector through an integrated suite of reforms. The outcomes to date reinforce the view that these moves are internally compatible rather than pulling in opposite directions.

Farmer understanding and involvement are critical to the success of the project as a whole. Education as to the nature of the system, its assets and the environmental realities within which it operates, are critical elements: farmers know that they cannot “mine” the environment. When they accept, through an open set of books, what the scientific and financial facts are, they become a leader of reform, not a “millstone around the neck of progress”.

Farmers have to “own” the changes in water systems. They have to accept the responsibility for continuation of the system into the future, whether or not they actually own the assets. In order to achieve this, their franchise involves active participation in real decision making and an acceptance by Government that a fully articulated set of property rights for farmers is part of the financial deal. Otherwise, the system is not capable of dealing most flexibly with change in an increasingly volatile world.

The seemingly perverse results predicted by modelling that, within a band, water price increases such as are in train under the COAG reforms lead to increased agricultural prosperity, appear to be borne out in practice. This is because the new arrangements of trading and market flexibility favour the more efficient operators, provided distortion is removed.

Some things that should not be done include undertaking a program of reform at a time of historically low commodity prices, and moving without customer recognition or ownership of the problem. Timing and customer education are critical inputs to the process, and to neglect these is to invite disaster.

Some of the issues raised in this paper are peculiar to Australia, existing as it does as a Federation of States. But many issues are likely, in reality, to be common to most jurisdictions when trying to implement a proper water policy.

Australia has a framework for dealing with most of this through its formal dealings between the States, and the prospect that a common framework, albeit with “under construction” signs on parts of it, will provide the way ahead.

The suite of water reforms, encompassing pricing, property rights, institutional reform and environmental considerations, has created the conditions for accelerating a national approach to overall water management. It is the suite rather than any individual part which will provide the greatest benefit. Each aspect is only a partial solution.

The extent to which the water sector may be considered on a competitively neutral basis with the private sector is under scrutiny at present, with indications being that the role of Government will be less relevant as a shield for cost reduction than in the past, although a common international definition of full cost recovery could be quite interesting to pursue in the interests of freer agricultural trade, especially as a State based agreement has proved to be a challenge.

This process has been very costly to date in terms of customer time and commitment, as well as Government time and effort. It is still based on inadequate science, especially in relation to environmental outcomes, and further movement can be expected in future.

Proper pricing alone solves little. It is a limited solution to a fiscal or allocative problem.. But when it is combined with the implementation of an undistorted trading environment, institutional reform involving real devolution to farming groups (with or without asset transfer) and a tough regulatory framework, as well as an appreciation of the fact that farmers and “the environment” can achieve a win-win outcome by a genuine understanding of synergies, the result should be a dynamic and vibrant agricultural sector which is adaptive to change and capable of achieving much better financial and environmental outcomes.

This is a long way from the early 1980’s approach — of offering subsidies. By the year 2000, it is likely that the Australian water sector reforms will be seen to be a positive contributor to better agricultural performance, a sustainable environmental performance, and a more nationally consistent set of outcomes.

Subsidies to agriculture through artificially low water prices restrain irrigated agriculture and stop it reforming to become a more profitable farm sector, as does the prevention of water trading on even-handed terms. Subsidies include the failure to price environmental “bads” in the cost of water. Water subsidies and a fixed allocation system keep farmers poor.

APPENDIX

Council of Australian Governments Water Reform

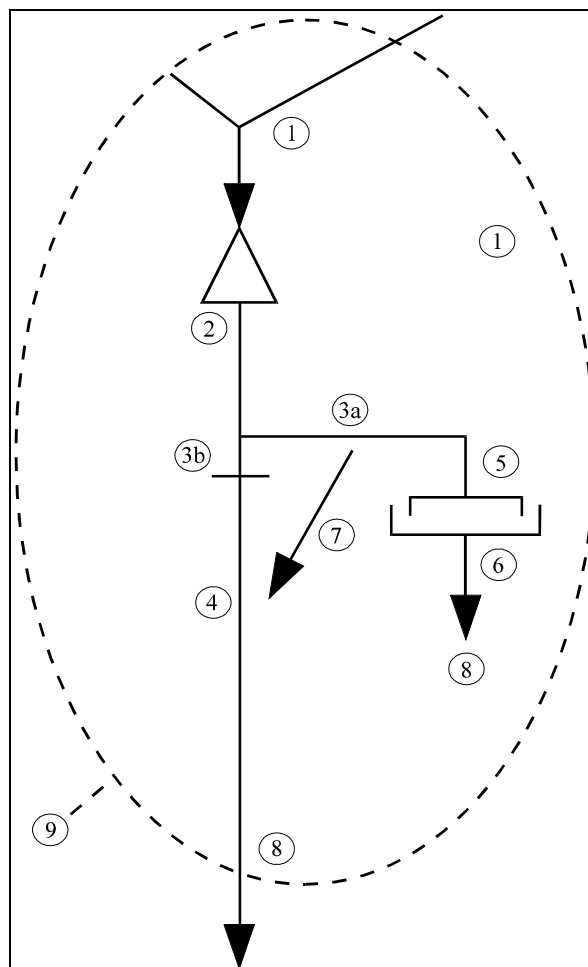
In February 1994 the Council of Australian Governments (COAG) endorsed an agreement for the sustainable reform of the water industry by the adoption of the Neal Report. Briefly, the following principles for reform of pricing in the rural water industry were adopted:

- By 2001, charges to comply with the principle of full cost recovery with any subsidies made transparent.
- Positive real rate of return to be achieved on the written down replacement cost of assets in rural water supply by 2001, wherever practicable.
- Future investments in new schemes or extensions to existing schemes to be undertaken only after appraisal indicates that it is economically viable and ecologically sustainable.
- Where trading in water could occur across State boundaries, the pricing and asset valuation arrangements should be consistent.
- Funds to be set aside for future asset refurbishment and/or upgrading of government supplied water infrastructure.
- From water charges, funds to be provided for the future maintenance, refurbishment and upgrading of the headworks and other structures under the control of the Murray-Darling Basin Commission.

In May 1995 a timetable to implement these reforms, amongst others, was agreed upon by all governments with the signing of the Competition Principles Agreement. Under this Agreement each State must produce a policy statement specifying the application of the competition principles to government activities. Complying with the reforms is now linked to each State obtaining the second installment payments under the National Competition Policy reforms.

In relation to pricing, a number of water activities in an “any catchment” depiction were described as the basis for dissecting costs further.

Figure 1. COAG Model Water Business



Source: COAG 1995.

In addition to the beneficiary/impactor pays principle, the 1995 report by the COAG Expert Group on Asset Valuation Methods and Cost-Recovery Definitions for the Australian Water Industry provided a description of a generalised water business based on a model catchment for cost identification purposes (Figure 1). The Expert Group identified nine cost categories, primarily to ensure a uniform definition of ‘water sector’ in each jurisdiction for the purposes of recovery through water pricing. These categories have been used to group water activities in a clear and transparent manner, and to ensure each water sector is similar to those in other jurisdictions. This helps to ensure consistency in pricing across State boundaries. The nine categories are:

1. *Catchment management* — those activities which are undertaken upstream of a water supply (or the land above aquifer intake areas in the case of groundwater) in order to protect the quality or quantity of water. It also covers catchment management activities generally which are undertaken to improve or protect the health of river catchments in order to conserve and protect water resources.

- (This includes the assessment of quantity and quality of water resources, monitoring programs including community programs, review of environmental impact statements and environmental advice, river corridor protection activities and plans).
2. *Operation and management of storage for water regulation* — including the in-year capital construction charge, maintenance, refurbishment and operation of dams, weirs and in-river works for water supply, and dams and re-regulation works.
(This includes dam operation and maintenance, safety surveillance, flood airspace studies and feasibility studies for new works, maintenance of the stream gauging and bore monitoring networks).
 3. (a) *Operation and maintenance of diversion system* — the associated activities required to deliver water from the storage to the point of diversion by the water users and the management of diversion from the supply source including bore holes.
(This includes the licensing of works for water supply, surveillance of diversions, administration of water transfers, the water ordering system, metering of water use and billing, as well as the operation and maintenance of the channel systems.
(b) *Operation and maintenance of diversion from the supply source* — where water is diverted directly from rivers and bores to a distribution area.
 4. *Waterway management along the river* — involves works undertaken as a result of the impact of regulating flows for water supply.
(This includes remedial work on river banks and channels, management of vegetation in river channels, monitoring impacts on riverine and instream flora and fauna.); *levee banks, watercourse diversion, referable dams, private weirs included in this.*
 5. *Operation and management of the supply distribution system* — covers the bulk distribution from the storage and regulating works and the diversion from the supply source including bore holes.
(In addition to operation, maintenance and renewal of the distribution system, this includes licensing of supply works for water supply, surveillance of diversions, administration of water transfers, maintenance of stream gauging and bore monitoring networks, metering of water use and billing).
 6. *Effluent collection, treatment and management:* (urban sewerage systems — not relevant to bulk rural water pricing).
 7. *Drainage collection and management:* (urban — not relevant to bulk rural water pricing).
 8. *Activities required to manage the “downstream impacts” associated with the water use* — involves activities to reverse or manage any impact caused by water extraction and use such as nutrient enrichment, chemical contamination or increased salinity of surface or groundwater resources, habitat loss. This is the “externalities” component.
(This includes policies for environmental allocations and flows, nutrient control programs, measures to control rising watertables and land salinisation caused by irrigation, investigation of changed watering regimes in forests and wetlands).

9. *Corporate management* — covers corporate management and administration of activities related to water management, including development of water law and water industry accountability indicators).

COAG has enunciated three fundamental principles relating to water pricing: full cost recovery; recovery of the full economic costs of providing services; and transparency of costs and subsidies.

Full cost recovery

The COAG Communiqué of February 1995 states that, in relation to commercial water functions such as urban water supply and rural water supply, “*where charges do not currently fully recover the costs of supplying water to users, charges and costs must be progressively reviewed so that no later than 2001 they comply with the principle of full cost recovery*”.

Figure 2. Cost definition

Economic Costs	Accounting Costs
Includes all costs attributable to the entity, including externalities which are not recorded in the accounts of the entity.	Only includes costs incurred by the entity and recorded in the accounts of the entity.
Are governed by economic principles and objectives.	Are governed by Australian accounting standards.
<i>Economic costs comprise:</i>	<i>Accounting costs comprise:</i>
Opportunity cost of capital.	
Externalities e.g. salinity impacts.	
Finance costs, including returns, dividends, retained earnings.	Finance costs.
Depreciation based on replacement costs of assets (or renewals).	Depreciation based on accounting standards.
Administration costs.	Administration costs.
Operations and maintenance costs.	

Full economic costs

In 1995, COAG also provided guidelines for identifying water management costs. It defined costs in terms of economic costs and accounting costs as shown in Figure 2, and concluded that accounting costs have so far been given the greatest emphasis by Australian entities. Economic costs include *all* costs of water management including the costs associated with dealing with the impacts of water use and abstraction.

Transparency of costs and subsidies

In February 1995, COAG agreed that all water services across the country should reach full cost recovery. The prices set to achieve the recovery of the full economic costs of water services must be transparent, in that each user must be able to have a clear understanding of what services s/he is paying for, and must be able to see clearly any cross subsidies a given government may choose to permit.

THE IMPACT OF AGRICULTURE ON WATER QUALITY

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World-wide concern continues to grow regarding the impact of agricultural activities on water quality and the environment. Agricultural water use has led to the elimination and reduction of many water-dependent ecosystems, depleted and modified water resources, and contaminated ecosystems and bodies of water. This paper classifies these impacts and suggests a number of policies to address a number of agricultural production problems which require specialised analysis and possible policy intervention.

The first five sections below focus on some of the causes and possible solutions for several water and environmental quality problems caused by agricultural activities. These include: 1) water diversion and restoration projects; 2) water contamination by crop systems; 3) water contamination by livestock systems; 4) waterlogging and drainage; and 5) sea water intrusion. The next section considers the impacts of past and present agricultural, environmental, and water policies on water and environmental quality. The concluding section identifies components of policy reform that aim to improve both water quality and productivity.

1. Water diversion and restoration projects

Water projects that modify water-dependent ecosystems by constructing dams or canals and diverting water have had, perhaps, the most significant impact on the environment and water quality. About 500 000 kilometres of waterways had been altered world-wide by 1980, and about 40 000 dams over 15 meters high had been built by 1985. Most of this extensive construction has occurred since World War II. Many major river systems, including the Rhine, Mississippi, and Colorado have been significantly modified. Today the Rhine is cut off from 90 per cent of its flood plain, flows twice as fast, and is a flood threat. The river's salmon fishery has been decimated, while 100 years ago it supported an annual catch of 150 000 fish.

Water projects serve several non-agricultural purposes, including navigation, power generation, flood protection, and water diversion for municipal and industrial purposes. But since agriculture consumes 80 per cent or more of the water resources in many semi-arid regions (western U.S., Australia, Turkey, Spain, Chile), and since navigation and hydroelectric power in many regions were essential for agricultural development, agricultural considerations were often paramount in the design and construction of water projects.

Water projects may negatively affect the environment and water quality in several ways. They cause destruction of ecosystems and species by damming and diverting water; they negatively affect fisheries through water supply reduction, changes in temperature, and barriers to migration and spawning; they lead to excessive erosion and sedimentation, lower dissolved oxygen concentrations, nutrient loading from agricultural and waste disposal, and transmission of exotic species that may damage native populations.

On the positive side, water development projects have played a vital role in assuring regular and plentiful food supplies. Even an ardent environmentalist such as Mark Reisner agrees that many water projects have been socially beneficial. Some water development projects, for example, flood protection projects, may also provide significant environmental benefits. However, there is now a broad consensus that many water projects were overbuilt in the past and that future proposals for new projects need closer scrutiny.

Reasons for over-construction of water projects

1. *Little regard for efficiency in project development choices:* Decisions regarding new developments are political, and economic analysis provides only one input to the political process. Many past development decisions were made without formal benefit-cost analysis, and/or water projects were established despite their low benefit-cost ratio. Since the mid-1970s, project proposals at some of the major water agencies in the United States (Army Corps of Engineers, Bureau of Reclamation) have been required to pass a benefit-cost test. Despite flaws in the procedures (Zilberman *et al.*), such benefit-cost tests have been largely responsible for the small number of water projects built by these agencies in the last 20 years.
2. *Restrictions on water trading and underpriced water to agriculture:* Market mechanisms and efficiency pricing are rarely used to allocate water. Frequently water allocation is governed by water rights regimes (such as the prior appropriation rights system) that require users to “use it or lose it” and restrict trades. Ground water prices may be subsidised (often through subsidised energy prices). Such cheap agricultural water discourages adoption of water conservation technologies and leads to overuse. This may deplete ground water aquifers and exhaust surface water supplies, causing water scarcity crises that are “solved” by construction of new diversion projects. These perceived “water scarcity crises” are actually water management crises, and reform of water allocation schemes leading to efficient pricing will reduce the pressure to build new projects.
3. *Environmental impacts of proposed projects neglected:* Until relatively recently, a general lack of awareness or appreciation of environmental consequences led to decision-making procedures that put little effort into investigating how water projects would affect ecosystems, wildlife, and fisheries. Only in the last 20 years have formal environmental impact studies been introduced as part of project evaluation procedures. Integrating economic and environmental impacts in the assessment process can be tricky. For example, there is not a consensus about how to monetise environmental impacts. The use of contingent evaluation methods continues to be controversial despite much progress (Mitchell and Carson). It is very difficult to provide concise measures of

environmental impacts that can be compared to economic benefits, yet this challenge must be met in project assessment procedures in the future.

4. *Lack of interdisciplinary input in project assessment and design:* At least in the United States, most of the agencies that design water projects have been dominated by engineers. In some cases, the input of economists, ecologists, or biologists has not been solicited or incorporated (Zilberman *et al.*). This lack of interdisciplinary input has led to:
 - *Emphasis on structural solutions for water resource problems.* Until recently new water diversion projects were proposed in response to perceived water supply shortages. Little attention was given to non-structural solutions, such as designing new institutions or policies, to induce more efficient use of water resources. Structural solutions are more expensive and can result in more extreme environmental effects. Increased consideration of non-structural measures may lead to reduced environmental damage.
 - *New project designs ignored efficient mechanisms for water allocation and management.* Many projects heavily subsidised agricultural water and restricted water trading and transfer. This effectively removed incentives to adopt water conservation practices and instead provided incentives to irrigate low-value crops. In some case, this practice has led to excessive transfer of water from environmental to agricultural applications.
5. *Flaws in benefit-cost analysis to assess water project proposals:* Even when benefit-cost analysis is incorporated as part of the policy process, there can be problems associated with its use:
 - *Failure to consider irreversible impacts.* Water projects may irreversibly impact the environment, technological changes may increase the productivity of water use in agriculture, and the demand for environmental amenities may increase. Failure to consider such factors in benefit-cost analysis may result in poor policy recommendations and lead to construction of excess, premature, or oversized water projects (Arrow and Fisher).
 - *Subsidised output prices versus efficiency prices.* Using subsidised output prices in the cost-benefit calculations may lead to overstating the benefits of proposed agricultural water projects, sometimes by 46 per cent or more (Lichtenberg and Zilberman).
 - *Failure to consider the cost of drainage removal.* Failure to consider this and other measures required to address waterlogging may contribute to overestimating the net benefits of water projects.

Improved project design and restoration projects

Decisions regarding new water projects will become more efficient as: 1) benefit-cost analyses and environmental impact studies are introduced in the project design and evaluation process; 2) water

quantities are efficiently allocated (i.e. trading is allowed); and 3) political considerations are not allowed to dominate water determination. At least in the United States, improved decision making has already led to construction of fewer and smaller water projects, less transfer of water from the environment to agriculture, and reduced negative side effects of water projects.

Growing recognition that past diversion of water resources was excessive, and increased concern with environmental quality and preservation of endangered species, has led to regulations aimed at restoring water-dependent ecosystems. Some of the ingredients of these policies include:

1. *Recognition that environmental uses of water are beneficial.* Existing water rights and the interpretation of water laws in many regimes may prevent water transfer for environmental purposes. Under some water rights systems (riparian, prior appropriation), water rights owners may use water only in activities that are deemed “beneficial”. Unfortunately in-stream uses and other applications of water for environmental purposes have not been considered beneficial. An important step toward pursuing environmental objectives is to categorise these activities as beneficial.
2. *Legalising water trades and transfers.* Legal restriction of water transfers and trading may prevent execution of restoration plans. For example, the “use it or lose it” requirement of the prior appropriation systems and the ban on sale of water rights in many regions prevents water purchases for environmental purposes. A reform that would enable water trading is needed to facilitate environmental projects (of course, water trading should be scrutinised for its environmental effects at the region of origin).
3. *Allocating water rights for environmental purposes.* Water rights for most bodies of water have already been appropriated, and even when transfers are legalised, the capacity to obtain water for restoration and ecological purposes may be limited. Reforms that reallocate water for quality improvement provide environmental agencies with a resource base for their activities. For example, the 1992 Central Valley Improvement Act in the United States sanctioned 800 000 acre-feet of water for environmental uses and allowed water trading for agricultural use. Shah and Zilberman argued that reforms that reduced overall water availability to agricultural users but allowed them to trade and transfer water might be welfare-enhancing for farmers and thus less likely to encounter any objections. Encouraging users to trade water while reducing the volume of water they control may be one way to generate sources of water for environmental purposes.
4. *Establishing purchasing funds.* Government agencies or private sectors may allocate money dedicated to the purchase of water rights—both permanently and on a seasonal basis—in order to obtain water for environmental purposes. The Nature Conservancy is one private agency that pursues this strategy. As the capacity for water trading expands, such agencies will become more effective. The U.S. Conservation Research Program is probably the largest purchasing fund in the world. While most of its activities are aimed at purchasing lands, it is slowly moving toward purchasing water, as is the Nature Conservancy.

In the past many of the activities aimed at land purchase were actually used to address water quality issues. For example, lands have been purchased to obtain the water rights assigned to them. This strategy has been used by urban developers to obtain water from

the agricultural sector. There is no reason why such a strategy could not be used for environmental purposes. Indeed, U.S. Fish and Wildlife Service enacted a purchasing fund to buy lands (for their water rights) so that Pyramid Lake in the State of Nevada would be sustained. A major issue of debate is how much of the public budget should be allocated for purchasing funds to improve environmental resources.

5. *Matching private contributions to purchasing funds.* Because of the public good nature of environmental amenities, there is likely to be under-investment in purchasing natural resources for environmental protection by the private sector. Therefore, there is a *prima facie* case for public sector intervention. The use of contingent valuation mechanisms to assess public willingness to pay for purchasing environmental amenities may be limited because of differences between the stated and actual willingness to pay. Therefore, developing programs where public funds will match private contributions for purchasing funds may be desirable. One step in this direction would be to make contributions for environmental activities tax deductible. However, more research needs to be conducted to determine the amount of public money that would be needed to complement private contributions to purchasing funds.
6. *Developing and implementing accountability criteria for restoration projects.* There are several major watershed restoration projects around the world (e.g. California and Florida in the U.S. and the Rhone and Rhine Rivers in Europe). The notion of restoration projects should not be taken too literally because biological systems are evolving. Instead, one can view them as projects that conserve, protect, and even improve the environment. It is important to develop economic criteria for assessing the efficiency of the proposed plans of such projects so that the shortcomings associated with the design and management of traditional diversion projects will not repeat themselves in restoration projects. Various types of indicators have been used to set objectives and measure the performance of environmental projects. Sound economic analysis is important in translating biological and chemical indicators into utilitarian terms. The notion of utility can be interpreted very broadly, as in the recent literature in environmental economics (Randall). We hope it will be feasible to develop benefit-cost mechanisms to assess restoration projects. If it is not feasible, it is important to establish procedures that will follow the Baumol and Oates idea of pursuing the least-cost strategies to achieve environmental objectives.

2. Water contamination by crop systems

One of the most persistent environmental problems over the last 50 years has been contamination of ground and surface water by agricultural chemicals and residues. Many air pollution problems have eased and industrial water problems have become less acute, but we have seen little progress in addressing agricultural contamination. These problems continue to be a major issue of policy debates.

There are several major contamination problems caused by crop systems. Pesticide residues can contaminate surface water through run off, and aerial sprays can leach to ground water reservoirs. Similarly, surface and ground water may be contaminated by residues of chemical fertilisers, salts, and other substances. Soil erosion is another source of surface water contamination.

The U.S. Environmental Protection Agency (EPA) has estimated that in 1990 at least 50 per cent of U.S. drinking water had detectable nitrate levels, although only about 2 per cent of the wells tested had nitrate concentrations above EPA-recommended levels. While 4 per cent of domestic wells contained detectable levels of pesticides, only 1 per cent had concentrations sufficiently high to cause unacceptable risks to human health. Ribaud estimated that the impact of cropland erosion in the United States in the last 1980s was around \$3 billion annually. Pimental provided several estimates of the damage of pesticides, which suggest that their overall water quality effects are around \$1 billion annually.

Contamination of surface water from agricultural pollutant runoff and aerial spraying causes death and deformities in fish and other life forms, makes fish and plants unsafe for human or animal consumption, and destroys possible sources of drinking and (sometimes) irrigation water. As water becomes more saline, its quality declines drastically. Many salt-intolerant plants cannot grow at all or require higher quality water for greater yields. Deep percolation of chemically contaminated ground water has made water in several important reservoirs unsafe for drinking, requiring a high cost of treatment in terms of cleanup and filtration. However, there is a significant variability of ground water quality. In most locations in the United States, ground water quality is reasonably good, and it can be used for drinking without much investment in cleanup. In some cases (e.g. the Fresno area in California, where DBCP has been a major problem), chemical contamination of ground water may increase water prices more than five-fold.

The pollution generation process

Chemical contamination can occur from residues that accumulate in the soil, run off into streams, and leach into deep-percolating ground water (Khanna and Zilberman). The volume of contaminated residues per unit of land depends on: 1) the actual application level of chemicals; 2) the technology of application and irrigation; 3) tillage systems and soil conditions; and 4) other environmental and topographical conditions. The impact of technological choice on pollution warrants more clarification. Not all applied inputs are consumed by the crop, and different application technologies have various input use efficiencies (fraction of applied input actually used). There is a growing trend to introduce what can be generically called “precision technologies”. These adjust input use to changes in environmental and geographical conditions and tend to increase input use efficiencies. Such technologies may include drip irrigation, chemical application based on Geographic Information Systems and Geographic Position Systems, and low-value high-accuracy pesticide application.

Thus, higher percentages of applied chemicals will contaminate bodies of water if aerially sprayed rather than applied by low-volume precision technology equipment. Similarly, if flood irrigation is used instead of mixing chemicals with water and “chemigating”, a larger percentage of applied chemicals end up in runoff or deep-percolating ground water. In the case of key chemicals such as nitrates, it is very important for the applicator to know the nitrate content of the soil. Where the soil is saturated with nitrates, extra applications will result in significant pollution.

Similarly, the selection of crops and cultural practices is crucial in preventing soil erosion. Tillage-intensive farming on steep land may result in high levels of soil erosion, and switching to low tillage may reduce soil erosion dramatically. Thus, understanding the technical dependency and the spatial heterogeneity of chemical contamination problems is crucial. The varying degrees of dimensionality and complexity make some textbook solutions for externality problems and crop systems difficult to apply.

The process of transition from chemical use in agriculture to environmental and health damage is complex and requires interdisciplinary analysis. Antle and Capalbo (1991) provided an economic decision-making framework that models elements of the processes of pollution generation, transport, and fate. Several empirical models incorporate elements of this framework (see Bogess *et al.*). Policy interventions to reduce environmental and health effects of water contamination may include measures to reduce residues and exposure to toxic materials by humans and other species.

Solutions to agricultural pollution

Water contamination problems by agriculture generally are of a nonpoint nature. It is often impossible to identify which producer is the source of pollution damage, and this hampers policy solutions. The wide array of possible solutions vary in their economic efficiency and the information they require for implementation. Some of these include:

1. *Pollution tax.* The first-best solution for externality problems is a pollution tax where the polluter is required to pay the marginal damage that he/she causes. However, with the nonpoint nature of agricultural pollution problems, such solutions cannot be implemented. Therefore, economists and policy makers continue to search for alternative policies, some of which are discussed below. Implementation of such policies depends on the availability of information as well as political economy factors. Optimal solutions can change over time as more knowledge becomes available and as the ability to monitor pollution activities improves.
2. *Tradable permits.* Buchanan and Turlock argued that taxing pollution may encounter political objections. Optimal resource allocation can be attained if governments set a limit on overall pollution and introduce tradable pollution permits. Under this solution, the price of the permit will equal the marginal cost of the pollution damage, but producers' incomes are higher than under taxation. Thus, they are less likely to object. Implementation of tradable permit markets encounters several difficulties. First, such markets must be sufficiently large to have heterogeneous producers that will gain from trade, but their size must be constrained by the magnitude of the region with the environmental problem the markets address. Second, allocation of initial rights may be tricky. The solution in many cases is to allocate pollution rights in proportion to historical rights. Third, the same nonpoint problem of agricultural pollution that plagues taxes also hinders tradable permits.
3. *Taxing variables that are correlated with residues.* Such tax policies or transferable permits should not be too complex. In essence, policy makers must look for simple solutions to complex problems. The need to develop relatively simple solutions to agricultural pollution problems excludes the application of many taxation schemes that derive from the "truth-revealing" literature. This literature argues that in many cases we have a problem of asymmetric information—individual decision makers know the pollution they cause but policy makers cannot identify the source or level of pollution. If policy makers have information about producers' output, the technology, and the relationship between production and pollution, they may be able to develop non-linear taxes resulting in a first-best solution. Such taxation may not be practical, however, because of complexity and data requirements.

4. *Output taxes.* Output taxes may be a proxy for the pollution tax. However, an output tax may be counterproductive, especially in cases where farmers may use more than one technology and are subject to different environmental circumstances. Khanna and Zilberman argue that, with output taxes, producers who adopt precision technologies (which adjust input use to exact conditions and lead to less revenue), will have higher levels of outputs and will have to pay higher taxes. In these cases, introducing an output tax to address pollution problems would be counterproductive since it would distort the incentive to adopt precision technologies that tend to reduce pollution.
5. *Input taxes.* Taxing inputs such as fertilisers, or pesticides may be superior to output taxes for pollution control. Experiments with such financial incentives have been tried in several European countries. These types of policies are especially useful in situations where farmers use the same technology. Even in cases where farmers apply precision farming technologies, input taxes are more sound than output taxes because such farmers often use less inputs. Thus, taxes on inputs will provide extra incentives to adopt precision technology. Still, there may be a big difference in the marginal damage from individuals using inputs with different application technologies. Therefore, a more efficient tax should depend on levels of input use as well as application technology.

An input tax that varies spatially and depends on application technology may result in outcomes close to the optimal pollution tax. However, it is much more difficult to implement than a uniform input tax, which can be imposed as a sales tax. Thus, in many cases a sales tax on fertilisers or pesticides may be a reasonable solution. One way to address the growers' resistance to input taxation is to introduce a technology subsidy scheme that will utilise some of the tax proceeds. Growers would know that the taxes they paid would subsidise adoption of precision technology and support research and development. For example, in the case of pesticides, such research might develop non-chemical alternatives to be used in a regional campaign to address pollution problems.

6. *Direct control of production activities.* The main advantage of taxes and other financial incentives, such as transferable permits, over direct control to address pollution problems is that optimal taxes are uniform even though producers may be heterogeneous in terms of their production relationships. However, when there is heterogeneity in terms of the damage associated with input use, uniform taxes are suboptimal. Taxes on pollution or input use should vary, and transferable permits must be adjusted for location. In both cases, financial incentives will lose their advantage over direct controls. Environmental policies that direct input use by farmers at various locations may be quite appealing if the policies are agronomically sound and adjusted to spatial variability. Direct control is objectionable in most situations, as policy makers may not be familiar with farmers and their circumstances.
7. *Technology subsidies.* A policy mix where financial incentives rely on the use of certain practices seems very promising. In many countries, farmers who use integrated pest management, soil testing, or non-tillage practices are subsidised. Financial incentives may include direct subsidies for adoption of environmentally-friendly technologies, subsidised credit for investment, and loan guarantees. Another interesting

approach is to condition participation in government support programs on use of certain practices.

8. *Purchasing funds.* Babcock *et al.* demonstrated that, in the United States, most environmental degradation is associated with both soil erosion and ground water contamination, and much of the damage is concentrated in relatively small areas of riparian zones. In some cases it may be practical to consider the use of purchasing funds to remove the most vulnerable areas from production or at least to divert them from using environmentally-threatening practices. The U.S. Conservation Reserve Program was designed for this purpose. In the past its mission was, given its budget, to maximise the lands enrolled in the program. However, Babcock *et al.* showed that it would be much more effective if its resources were targeted to get the maximum benefit per dollar spent. Their analysis showed that targeting the right acreage can eliminate much of the ground contamination and soil erosion problems at relatively low cost.

3. Water contamination from agricultural livestock systems

Although often attributed to crop systems, animal waste contamination of surface water in many regions originates in livestock systems. A significant amount of water pollution, particularly nitrate contamination, is the result of animal wastes being disposed in areas used to grow pasture and other crops. In the U.S. over-application of these waste products has resulted in severe water quality problems in the Plains, the Los Angeles area in California, the Mississippi Delta, among other regions. In many areas, animal waste problems are more severe than water contamination by crop systems.

Solutions to animal waste problems often encounter the same nonpoint source problem that plagues crop system pollution. However, for animal waste, different types of information may permit workable taxation schemes. A uniform tax per head of livestock is likely to be suboptimal because livestock facilities at different locations may cause different environmental damage, and surface water contamination depends not only on the number of cows but the number of cows per disposal unit of land. Hochman *et al.* suggested a tax on cows per disposal acre to address dairy waste contamination in California. This solution would induce dairies and other livestock operations to transport some of their waste to environmentally-sound disposal areas, and the modelled outcome was very close to the first-best solution. In some cases the disposal areas actually provide a social benefit through fertiliser or composting. Since livestock operations often are concentrated in small regions, incentives for transportation may be desirable. Regulators need to require waste accounting that will provide an accurate measure of the amount of waste to be taxed or otherwise regulated. Effective taxation of disposed waste may encourage either recycling or exporting animal wastes. It would reduce some of the problems associated with separating livestock and crop production in modern agriculture.

Because of spatial variability, even when there are schemes based on waste accounting, the penalty for waste generation should depend on the location of livestock operations. Waste disposal activities in riparian areas should be much more restricted than in areas further away from surface water. Similarly, regulations should be stricter in locations containing sandy soils and percolating water than in areas with solid, heavy soils.

Pollution of both crop and livestock systems is affected by random events such as storms. The design of pollution control measures have to recognise these temporal variabilities and enable containing residues with a high degree of reliability. The benefit cost calculations to assess alternative solutions should explicitly incorporate the randomness of the pollution-causing phenomenon.

There is a growing tendency to regulate large livestock operations because of the water contamination problems they pose. However, there does not seem to be an inherent relationship between size and pollution *per se*. In many cases, the aggregate pollution by small operations may be more severe than by large ones. Furthermore, for a large integrated operation, the integrator should be liable for all the waste problems, and the nonpoint problem may become a point problem. Thus, size is not necessarily a cause for pollution, and policies that aim to address water quality problems associated with animal wastes should address the waste problem rather than the size.

In all pollution problems, technology can play an important role in changing the nature of the optimal solution. Recycling, composting, and other technologies for reusing waste may provide cheaper alternatives for waste handling. There are economic benefits to provide financial incentives that will lead to their adoption. Similarly, the development of monitoring technologies will help regulators to better trace the sources of pollution and expedite the transfer of nonpoint waste problems to point source problems. Governments should support research to develop monitoring technologies and, once these are available, should subsidise their introduction and adoption.¹⁰

4. Waterlogging and drainage

One of the most significant side effects of agricultural irrigation has been the problem of waterlogging. Historically, this problem decimated civilisations in Mesopotamia and many other parts of the world. Waterlogging is caused by an impenetrable layer of clay not far below the surface. Deep-percolating water from irrigation or rainfall accumulates and, when it reaches the topsoil, creates salinity and drainage problems, which eventually eliminate agricultural productivity. The most effective long-term solution to waterlogging problems involves draining ground water by installing tiles under the irrigated fields to carry the percolating water to drainage canals, which convey it to disposal areas such as oceans and seas.

For economic or environmental reasons, drainage disposal may not be feasible. Resources may not be available because either the drainage projects cannot be justified economically or because there is no institutional infrastructure to support the collective action needed to design and implement such large projects. In addition, drainage water may be of low quality and contain salt and toxic minerals. In some cases it is very difficult to find an appropriate disposal area. For example, the State of California planned the construction of a large drainage canal from the San Joaquin Valley to the San Francisco Bay and Delta. However, this project encountered resistance because of environmental concerns. Currently, alternatives for disposal (for example, disposal in the Pacific Ocean) are very expensive, so other solutions for drainage projects are being sought. These include:

1. *Diversion of water to an area designated a fish and wildlife refuge.* This solution was unsuccessfully attempted in California. As the Kesterson case suggests (Dinar and

10. See Millock and Zilberman for a scheme that recognises heterogeneity among producers. It proposes differentiated taxes for adopters and nonadopters of monitoring technologies to help induce adoption of such technologies over time.

Zilberman), such an alternative may not be sustainable because the low quality of the drainage water can have harmful long-term effects on the wildlife being protected.

2. *Financial incentives to reduce waterlogging.* Several studies in Dinar and Zilberman model waterlogging as a non-renewable resource problem, where ground water capacity to accumulate deep-percolating water is a finite, exhaustible resource. The accumulation process can be optimally managed by economic incentives. For example, taxes can be based on drainage generation. When drainage is unobservable, taxation of water use (which may depend on irrigation technology or subsidising the adoption of water conservation technologies), will result in a decrease of deep percolation per unit of applied water because of higher water use efficiency.
3. *Conjunctive use.* Deep-percolating ground water can be reused for irrigation, and it can provide storage to complement surface water sources in periods of drought. Adoption of efficient irrigation technologies or reuse of ground water expands the economic life of a waterlogged region by prolonging the time it takes for the water level to reach the root zone.
4. *Evaporation ponds and cleanup facilities.* Evaporation ponds are especially effective if the volume of drainage water is low because farmers have adopted modern irrigation technologies, incentives, and recycling. Another solution may be provided by the construction of water cleanup facilities to remove salt and minerals from the water.
5. *Separate storage and conveyance facilities.* This drainage solution, which may be useful for other water quality problems, proposes separate storage and conveyance facilities for different water qualities. Fresh water would be conveyed for drinking, irrigated water for young plants and salt-sensitive crops, and lower-quality water for irrigating salt-tolerant crops. Water of only the lowest quality would be purified or evaporated.
6. *Fallowing the land.* The least-cost solution for waterlogging problems may be economic incentives to reduce agricultural intensity and increase fallowed land. Governments often invest large sums of money in attempts to prevent waterlogging or reclaim areas damaged by this activity. Benefit-cost analyses should be used to carefully assess these situations. If restoration and continued production in damaged or threatened areas are not economically justified, then agricultural production should be curtailed and the cost of the reclamation investment saved.

5. Sea-water intrusion

In many coastal regions around the world, over-pumping of ground water or excessive diversion may lead to sea-water intrusion, which may cause salinisation of fresh surface water and harm fish and wildlife in those ecosystems. In other cases, over-pumping of ground water leads to salt-water intrusion. This may cause irreversible damage to ground water aquifers because it compromises their capacity to retain fresh water from rainfall and other sources. The hydrologic literature on the protection of ground water aquifers against salt-water intrusion is intensive, and economists have developed an economic framework to address this phenomenon.

The risk of sea-water intrusion can be alleviated by: (1) control of ground water pumping and (2) diversion of fresh water resources to recharge the aquifer. The first set of policies requires collective action by local governments to monitor ground water reservoirs and control ground water pumping. When a large number of pumpers rely on the same aquifer, there is the potential for a tragedy of the commons because none of the individual pumpers sufficiently takes into account the future impacts of his/her actions on the aquifer. Local authorities can control the situation by imposing an extra water tax or establishing regional ground water pumping targets, introducing transferable permits, or even directly controlling each individual pump. Implementation of an optimum policy is not straightforward because of the need to adjust for spatial heterogeneity and differences in irrigation technology. Where there is a more severe risk of aquifer salinisation, one may consider a water project that diverts fresh water into the aquifer. During such a process, the ground water-dependent agricultural activities in the region would have to be curtailed and adjusted.

6. How government policies affect agricultural water externalities

Agricultural policies

Developed countries have implemented agricultural policies to support farmers' incomes and stabilise prices, which have led to an excess supply of agricultural commodities, resulting in low international commodity prices, while not boosting incomes of farmers. Each type of policy has its own affect on agricultural water use. Overall, however, such policies tend to increase the input-use intensity in agriculture and cause more severe agricultural water-use problems.

1. *Price Supports*: Price supports of agricultural commodities can significantly increase average prices and reduce domestic price variability. There is evidence that these policies augment agricultural supply by increasing input-use efficiency and expanding farmland (Zilberman and Lichtenberg). For example, with higher and more stable prices, farmers in the mid-western United States have expanded their irrigated land to the sandy soils of Kansas and Nebraska, and in Canada expansion has reached the desert regions of southern Saskatchewan. This expansion has depleted ground water, and concomitant intensive use of chemicals has contaminated ground water aquifers. Khanna and Zilberman have shown that higher commodity prices (because of price supports or other reasons) may lead to adoption of resource-conserving technologies, if these technologies are yield increasing. For example, higher commodity prices may trigger adoption of modern irrigation technologies that increase application accuracy and reduce residues, thus increasing yield and reducing pollution. However, the likelihood of adoption of cleaner technologies because of higher prices increases when the higher commodity prices are associated with stricter environmental regulations.
2. *Land Diversion Policies*: These policies assure farmers higher prices in exchange for reducing cultivated acreage; the diverted land is most often fallowed. The overall effect of such policies on input-use intensity is not clear because higher and more secure domestic commodity prices have enabled farmers to plant acreages more intensely. This has led to slippages so that the reduction in output was much smaller than the reduction in acreage. The high intensity of production results in higher volumes of fertilisers and pesticides, which may have negative effects on the environment and, in some cases, overcome the effect of the reduced acreage. Thus, the impact of diversion policies varies across locations. If low-quality, uneven land close to riparian zones is diverted,

such policies might have play an important role in improving environmental quality. On the other hand, if the planted acreage is in riparian areas or sandy soils with a low capacity to hold chemicals, then such policies may result in either ground or surface water pollution.

3. *Crop Insurance Schemes:* These policies reduce the price risk, increase average prices, and may enable production to take place in marginal lands where production would not have occurred otherwise (adverse selection, moral hazard). Such, crop insurance schemes may have a negative effect on the environment because of their impact on marginal lands and the expansion of agricultural land bases.
4. *Input Subsidies:* Governments in developed countries (and more importantly in developing countries) have from time to time subsidised inputs such as energy, water, fertilisers, and capital. By reducing the cost of inputs, these policies tend to expand the irrigated land base and the use of chemical inputs. Input subsidies might be considered the worse offenders of environmental quality in general. Developed nations such as the United States and EC nations have accumulated large inventories of dairy products that occasionally must be destroyed, reflecting the excess productive capacity of the dairy sector. These types of programs damage the environment by increasing both animal waste and the acreage of pasture crops to support a larger number of animals.
5. *Public research and extension:* To preserve the competitive nature of agriculture, governments have allocated significant resources for research and extension activities. These resources aim to complement the effort of the public sector and to provide technologies and knowledge that have public good properties. Such activities have led to development of management practices, such as biological control, that solve pest problems without the use of chemicals. These resources have been used to develop knowledge about water dynamics and water contamination and have been essential both in detecting and solving water quality problems.

Policies aimed at environmental protection

1. *Pesticide Regulations:* A wide array of government policies regulate pesticide registration and use. Generally, the government imposes numerous pesticide registrations that attempt to ban chemicals that might have a detrimental affect on humans or other species (Zilberman and Millock). These policies are largely responsible for the relatively small numbers of catastrophic events associated with agricultural pesticide use; however, this does not imply that these policies are efficient.

In some cases over-regulation may lead to concentration of market power in the chemical industry. This impedes the emergence of cheaper and safer alternatives and the survival of smaller producers. While the toxicology testing of new compounds may be very thorough, less attention has been given to investigating the movement of compounds in the ground and screening pesticides based on their environmental volatility. Ground-water contamination by DBCP, for example, seems to have been the result of an inability to predict the volatility of this chemical and its ease in penetrating ground water. This problem may reflect scientific and technical limitations. As research on chemical ground movements widens and mechanisms to simulate and assess

it become cheaper, these mechanisms should be incorporated into the regulatory process.

Policy regulation of pesticides includes registration and bans. Bans occur if the use of chemicals leads to discovery of negative properties (e.g. carcinogens). Because pesticide bans result in severe consequences, their imposition is rare and delayed. Therefore, it may be useful to introduce financial incentives (in the form of pesticide taxation) to reduce the use of pesticides and to encourage their application with more environmentally-sensitive technologies.

2. *Set-Aside Programs*: In the United States and many European countries, governments have developed programs which pay farmers not to utilise their lands. Such programs are designed to prevent soil erosion and, in the case of the U.S. Conservation Reserve Program, to protect environmental amenities. Set-aside programs, which are basically purchasing fund policies, are very important for environmental quality. If applied widely, they can significantly reduce agricultural pollution degradation systems and may be useful in improving environmental amenities.
3. *Species and Ecological Zone Protection Programs*: Most countries have programs similar to the U.S. Endangered Species Act that aim to preserve endangered or threatened species or delicate and valuable ecosystems. Such programs may restrict both diversion of water resources and agricultural production activities that might hamper protected species or ecosystems. Such programs have led to a reduction of water supplies available to agriculture by setting restrictions on interregional transfers and by requiring diversion of agricultural water as part of species protection or restoration plans. In addition, environmental protection considerations prevented implementation of several proposed water projects.

While environmental protection programs have achieved important environmental objectives, in many cases their design is flawed because they provide the wrong incentives¹¹ and/or are not cost effective (Ise *et al.*)

Water quality protection acts

Most countries have legislation to contain water contamination by toxins and waste products below certain target levels. Implementation of such legislation has led to the creation of institutional structures that monitor and enforce water quality standards through financial taxes and other incentives. In some countries, for example, there are harsh clean water regulations that establish stricter standards and set frameworks for safe drinking water.

Clean water legislation has had a significant impact on farmers in many regions. It provides the foundation to reduce contamination of ground and surface water by crop and livestock operations but is unlikely to lead to efficient economic outcomes. It is more convenient and “fair” to have uniform water quality standards for regions or countries. However, the marginal cost of achieving the quality

11. In some cases such programs may be counterproductive because they provide wrong incentives. For example, property owners who are aware that they will be penalised if an endangered species is found on their property may actually destroy it.

standards varies significantly across locations. Higher overall levels of environmental quality can be achieved for the same economic cost if quality standards vary across locations. A transition to flexible policies that recognise regional heterogeneity and consider the costs and benefits of establishing water quality regulations at various locations will improve environmental quality and/or market efficiency.

7. Conclusion: Towards sustainability

This paper identifies several ways agriculture has contributed to the deterioration of water quality and the environment. Several elements of policy reform can together contribute to the restoration of ecosystems and provide protection for water resources and the environment in the future. These elements include:

1. *Agricultural policy reform.* Overall water quality and the environment are likely to benefit from increased reliance on market forces in allocating resources in agriculture. In particular, removing barriers to trade in agricultural commodities and eliminating subsidies will encourage more efficient use of resources in the production of agricultural commodities. These policy reforms would prevent some of the overproduction of agricultural commodities in locations without relative advantage and reduce the excess utilisation of water and other resources that this entails. Gradual removal of agricultural support programs would be likely to increase the income of some of the more efficient producers. Finally, reduction in agricultural production supports may free resources to obtain environmental objectives in agriculture.
2. *Water policy reform.* Many water quality problems are rooted in mismanagement of water quantities. Eliminating policies that restrict water trading, encourage water consumption, and subsidise water prices is crucial to improved water quality. Higher water prices will lead to adoption of water conservation technologies and improved conveyance systems that will improve water use efficiency. This policy change would help reduce run-off, contamination of ground water, and the need for new water diversion projects. Introducing water trading regimes with minimal transactions costs will not eliminate the need to assess the environmental impacts of proposed water transfers, especially between regions. Water authorities must have the regulatory structure and capacity to enable water transfers that increase efficiency while preserving the environment.
3. *Environmental Policy Reform in Agriculture.* Water quality will obviously improve if the use of input contaminants are reduced. Thus, subsidies for chemical inputs such as pesticides and fertilisers should be eliminated, and disincentives to their use should be introduced. Greater effort should be devoted to obtaining the reliable quantification of environmental damage from chemical pollution that is necessary for first-best solutions. In any case, governments should strive to achieve their environmental objectives at least cost. Whenever feasible pollution fees or trading in pollution rights should be introduced. When monitoring pollution is not feasible, other incentives, such as taxes on chemical use and subsidies for environmentally-friendly practices such as Integrated Pest Management (IPM), should be introduced. Policies should recognise heterogeneity, vary by location, and adjust to random events. Thus, restrictions and even bans on production activities should be introduced in environmentally-sensitive

areas. Effective liability rules should be introduced and enforced to address mismanagement in the handling and use of chemical and waste products in agriculture. The fate of animal waste should be monitored, and incentives and institutions for safe recycling and reuse should be introduced. Thus, stricter water and environmental policies combined with agricultural policy reform, would lead to adoption of conservation technologies that would improve environmental quality.

4. *Reform of project evaluation procedures.* Many water quality problems are the result of poorly conceived projects. Development of mechanisms that will result in efficient and environmentally-sound projects are essential. Efficiency considerations should play a paramount role in water project assessment, and projects should pass well-executed benefit-cost tests. Thus, project assessment procedures must be revised to take into account irreversible impacts, uncertainty, non-structural solutions, and the possible cost of drainage removal. They should correct price outputs and inputs and consistently assess environmental benefit and costs.

Project evaluation must incorporate equity considerations and aim to reach consensus-based solutions. Project designs should be interdisciplinary, incorporating knowledge in biology and economics in addition to engineering. Environmental restoration projects should be treated as rigorously as water development projects.

5. *Continued research and education.* Much past damage was unintentional, reflecting ignorance and lack of education. Research on environmental quality issues has public good properties and should continue to be supported by the public sector. Research should aim to develop better mechanisms to monitor and detect environmental policy problems, and to develop technologies to increase input use efficiency and reduce residues. Knowledge propels policy changes. As new knowledge becomes available, policies and regulations will change. The development of satellite-based monitoring systems, new knowledge in ecology, and improved computer technologies should lead to changes in the regulatory process towards policies that are more efficient.

Despite the power of technology, complete monitoring of behaviour is unlikely to be possible. Voluntary restraint of agricultural producers is important to reduce contamination problems and improve water quality. Such restraint is a result of an improved awareness and sense of responsibility, and it and could be instilled by education.

6. *Incentives for voluntary environmental conservation projects.* Water quality policy has a preventive element in the form of incentives to reduce damage and a proactive element of restoration. The proactive aspects should be partially initiated and financed by governments through purchasing funds and restoration projects, but also have a strong capacity to take advantage of the private sector's willingness to pay for such activities. Governments should consider mechanisms to encourage collective actions by citizens to raise funds and donate resources for conservation projects. Given the public good nature of such activities, governments may provide matching funds and other support that will encourage private initiative in this area.

There is almost universal consensus about the desirability of sustainability, but it may have many interpretations. One interpretation of sustainable development is economic

growth while preserving environmental quality. When it comes to water quality, we have to strive to go beyond sustainability to aim for economic growth and improvement in environmental and water quality. The changes in policy embodied in the six points above can serve this aim.

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THE IMPACT OF AGRICULTURE ON WATER QUALITY: INDICATORS AND POLICY MEASURES

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1. Abstract

It is evident that agriculture affects water quality within countries of the Organisation for Economic Co-operation and Development (OECD). This impact is proportional to the wide range of agricultural practices and management intensity existing amongst these countries. Impact determination is complicated by the difficulty in assessing the many factors that govern the effect of agriculture on the environment. There is a public perception that water quality is worsening. Yet the public receives conflicting messages as to the severity of agricultural impact on water resources. One reason for differences of opinion on water quality is the way in which our individual attitudes on risk assessment affect how we choose to interpret water quality findings. Some take a “zero tolerance” approach to contaminants in the environment. Others hold that there are threshold levels below which the public is at reasonable risk. Water quality varies widely within and amongst OECD countries. It is, however, difficult to portray national averages because of, differences in pollutants monitored and environmental conditions, and limited or uneven data coverage.

Environmental indicators are an increasingly varied and flexible approach to tracking the effect of agriculture on water quality. To be effective, they must relate to existing water policy, be analytically sound and readily measurable. “State” indicators measure the existing level of contaminants in the environment, compared to an allowable standard determined by public authorities. These routinely include the measurement of chemical content, but in recent years a broader range of parameters, such as biological diversity, have received attention. “Risk” indicators are intended to provide an early warning of potential problems. These indicators are aimed at predicting the impact of agricultural contaminants on water quality, in a variety of time and space constraints. The Canadian *Indicator of Risk of Water Contamination* from nitrogen (IROWC-N) is an example.

Before implementing policy measures to address agriculture and water quality issues, society must first verify that there is indeed a significant problem to be corrected. Having done so, there is a social (public) off-farm cost to water quality loss that must be considered. A variety of policy instruments exist that place increasing emphasis on economic measures as a means of achieving environmental goals within fiscal and political constraints. But there are complications to this approach, such as those surrounding a nitrogen tax. In addition to monitoring and predicting the effect of agriculture on the environment, agriculture needs to take a proactive role in demonstrating where it has been a good

steward and its willingness to exercise due diligence in a time of change. A multi-disciplinary, multi-agency approach to water quality is required to effectively address agriculture's role in water resource management.

2. Agriculture and water quality

Objectives of this report

Concerns over water quality degradation continue to increase in OECD and other countries around the world. The wide-spread nature and increasing intensity of agricultural activities clearly reflect the risk that surface and groundwaters might become contaminated.

The objective of this report is to briefly look at what we think we know about the effect of agriculture on water quality, and some of the factors that govern that perception; then to examine the role of indicators as a mechanism whereby we can judge water quality; and briefly, to explore agricultural/environmental policy options that might control or prevent pollution from occurring. This report is intended to help policy makers better evaluate the overall impact of agriculture on water quality.

Contaminants of concern

Runoff, leachate, and airborne deposition from agricultural lands and intensive livestock operations may be contributing unacceptable levels of organic matter, sediment, agri-chemicals and bacteria to surface and groundwater supplies. This could result in a loss of oxygen in surface waters and their eutrophication, as well as leading to acidity and toxicity in surface and groundwaters, that could adversely affect water use and safety for human life and the entire ecosystem.

A range of agricultural conditions

Within OECD countries, a wide range of conditions result in a diversity of potential environmental challenges, as reflected in European Union (EU) countries (Szmedra 1994). During the late 1980s, for example, while the use of nitrogen (N) fertiliser decreased by 13-15 per cent in the Netherlands, Italy, and the UK; it remained the same in Denmark, Germany and Belgium; while increasing (10 per cent-15 per cent) in France, Ireland, Portugal and Spain. In terms of agrichemical use in Europe, France was the largest market, accounting for about 1/3 of sales in the western European Market. Average application rates for plant protection were as high as 18 kg/ha in the Netherlands, compared to average application in the US (including extensive low-input areas) of 2 kg/ha.

Southern European countries generally have poorer soils, and attempt to maintain small, marginally profitable farms that are linked to a traditional rural heritage and social structure. In Portugal, for example, 26 per cent of the land base is deemed suitable for agriculture, yet 46 per cent of the land is used for that purpose. In Spain, 60 per cent of farms are less than 5 hectares in size. Agriculture in northern Europe tends to be more intensive. In the Netherlands, more than 15 million tons of excess manure are produced annually. In Denmark, 32 agrichemicals have been withdrawn from the market because of perceived toxicity. In the former West Germany over a 30 year period (1960-1990); farm labour decreased 73 per cent, farmland area decreased 16 per cent, and total number of farms

decreased 55 per cent; while gross production per acre *increased* 93 per cent; the use of N fertiliser increased 150 per cent, and total agricultural production increased by 60 per cent.

Complicating agricultural effects

Attempts at addressing the potential effects of agricultural pollution on the environment are complicated by factors such as:

- **traceability** — it is often difficult to trace the origin and level of losses;
- **monitoring costs** — diffuse monitoring requirements results in higher costs;
- **number of farms** — the sheer number of farms and differences in management intensity makes it difficult to differentiate between source/effect;
- **physical differences** — no two farms are the same, having differences in physiographic setting and location;
- **time lag** — there is often a time lag in application/response relationships;
- **poorly understood interactions** — there is still a very poor understanding of many agricultural/environmental interactions;
- **climate variables** — which affect the environmental impacts, of for example, pesticide and fertiliser applications;
- **effect of agricultural policy:**
“Environmental management in agriculture is embedded in the larger structure of agricultural policy, and in many aspects is its hostage” (Runge 1994).

There are clear advantages to the control of potential contaminants. These advantages include: a reduction in water treatment costs; enhanced wildlife habitat; enhanced ecosystem diversity; and an improvement in the quality of recreational sites.

But, there exists a great deal of uncertainty as to the true impact and cost of agricultural pollution. Consequently:

“Inability to assess the costs of the environmental damages stemming from agriculture makes it difficult to determine the level of abatement effort necessary and the potential acceptability of the instruments attempting to achieve that effort” (Canadian Environment Bureau 1996).

3. Uncertainty and water quality

Public perception

There is a public perception that water quality is worsening. In Canada, an Angus Reid opinion poll showed that many residents see water pollution as “the most serious environmental danger facing the

world today.” Yet the public continues to receive conflicting messages about the role of agriculture in degrading water quality. In the United States, for example, some say that agriculture is a “major contributor” to water pollution (Offutt 1990), while on the Canadian prairies it is argued that there is “very little evidence” of such a condition (Lindwall 1992).

In many places, surface and groundwaters are said to be unacceptably degraded by agriculture. It is certain that agricultural “hot spots” of contamination occur. But how representative these findings are of the effect of agriculture in general can be very uncertain.

Opinions of risk

A central reason for differences of opinion on water quality, is that our individual attitudes towards acceptable risk greatly affect how we choose to interpret water quality information. Some are prepared to accept a “guidelines” approach to water quality — the notion that there are contaminant levels below which our lives and the health of the ecosystem are at reasonable risk. Others take a “zero tolerance” position and hold that no amount of unnatural substance or excessive nutrient level in the environment is acceptable. All of us are likely to adhere a little to each of these schools of thought, with most leaning more one way than the other.

Given the small concentration of agrichemical often involved, sampling and analysis protocol can play a major role in whether or not a residue is found — and at what levels. For example, shallow groundwater may need to be sampled weekly during the growing season, otherwise peak nitrate levels will be missed (Chang and Entz 1996), and large seasonal and spatial variations can occur in the herbicide levels of shallow groundwater (Hill *et al.* 1996). Still, even when trace agrichemicals are detected, the meaning of their detection is unclear (CAST 1992):

“The scientific community’s ability to detect chemicals is much more advanced than the understanding of the toxicology associated with such discoveries”.

Risk assessment

Risk assessment is at best an imprecise science, severely constrained by what Adam Finkel of the US Occupational Health and Safety Administration (OHSA) calls “a dearth of qualified practitioners” (1996). He cautions that we must be careful not to ask more of risk assessment than it can deliver. Scherer (1990) points out that traditional approaches to risk assessment involving probabilities, statistics and risk analysis are not sufficient in the public mind. He says that technical and scientific problems are ultimately social problems, and that public reaction to risk assessment is based on a set of criteria requiring both technical and social solutions.

The risk assessment criteria used by the public are more likely to focus on what Sandman calls an “Outrage Dimension” (Sandman 1987). This *outrage dimension* is based on the integration of up to 20 factors that include:

- ***Fairness of risk*** — accounting for an individual’s proximity to a hazard, like a nuclear reactor.

- **Degree of control** — access to a private well as opposed to relying on public water supply.
- **Familiarity** — exposure to common automobile accidents vs. more ‘exotic’ risks such as pesticide contamination.

Water quality in OECD countries

The range of problems encountered is extreme. For example, Canadian surface, ground, and marine waters are said to generally be of good quality. On the other hand, waters in Mexico are regarded as highly polluted — although it should be pointed out that most measurements there have been taken near developed or populated sites. The extent and severity of problems in other countries appears to be somewhere in between.

Classification difficulty

It is difficult to reliably portray a national average of overall water quality due to the range of pollutants, variety of environmental conditions and the limited or uneven coverage of data. This is largely due to inconsistencies in certain factors that include:

- **biased assessments** — existing findings may not reflect those of many other waters;
- **limited detections** — some agricultural contaminants may be reduced because they tend to bioaccumulate or are stored in sediment;
- **a holistic picture** can only be derived through associating chemical test results with physical, biological and economic data;
- **short term trends** — may be misleading due to climatic variability;
- **long term trends** are required to indicate whether and where pollution prevention and control should be reinforced;
- **spatial/temporal scale** — only certain environmental conditions can be accurately represented within various time frames and scales.

For example, the United States has considerable water quality data, yet, like many countries, lacks a consensus on national water quality conditions. According to the US Environmental Protection Agency (USEPA), agricultural sediment and nutrient loading are two of the chief contributors to degraded water quality in about 40 per cent of US lakes and rivers (USEPA 1994). Yet the US Department of Agriculture (USDA) Working Group on Water Quality observes that EPA estimates are based on a non-representative sampling of less than one-third of the nation’s waters, and conclude only that:

“The Working Group’s “worst case” estimate is that agriculture may be a factor in about 7 per cent of US waters which might not support the intended use specified by the respective State” (Swader *et al.* 1994).

Within Canada, some imply that field-scale agricultural practices are widely, unacceptably polluting surface and groundwaters across the prairies. Yet when the Prairie Farm Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada recently completed a survey of regional evidence, their central finding was that:

“Within the context of the Canadian Water Quality Guidelines, there is no significant body of evidence to indicate the wide-spread contamination of surface and groundwaters on the prairies from nonpoint-source agricultural activities” (Harker *et al.* 1997).

General trends in OECD countries

A few general trends are evident in nitrogen and phosphorus concentrations for waters of OECD countries when findings from the 1980s are compared with more recent evidence (OECD 1991, OECD 1995):

- In the downstream reach or near the mouth of rivers, mean annual concentration of *nitrates* has increased, but *phosphorus & ammonium* levels have decreased.
- Lake *phosphorus* levels have decreased, while *nitrogen* pollution has remained largely unchanged.
- In groundwater, many OECD countries have documented widespread and substantial increases in *nitrate*.

A number of countries have estimated the share of water pollution originating from agriculture. It is not always clear how these estimates were obtained, or whether they include discharges by the agri-food industry.

4. Indicators of water quality

The theory of indicators

Indicators are a way of allowing us to measure the effect of agriculture, both positive and negative, on the environment. Their effective use can reduce the total number of measurements and sampling parameters required to assess environmental impact. Indicators can simplify the process by which results are communicated to interested parties. As such:

“Environmental indicators are increasingly seen as necessary tools for helping to chart and track the course towards a sustainable future” (OECD 1994).

A Pressure-State-Response framework

Environmental indicators ought to reflect the results of a Pressure-State-Response framework (OECD 1994):

- **Pressure** — human activities exert pressure on the environment.

- **State** — pressures cause a quality/quantity change in the ‘state’ of natural resources.
- **Response** — societal response to these changes is reflected in environmental, economic and sectoral policies.
- Example:

Issue	Pressure	State	Response
Increasing Eutrophication	Intensification of livestock production	Concentrated N & P in surface water	Restricted livestock concentrations

Selection criteria

In general, environmental indicators should be selected according to the following criteria:

- **Policy relevance** — provide a representative picture of environmental conditions that is simple, easy to interpret, shows trends over time.
- **Analytical soundness** — theoretically well founded in technical and scientific terms, based on international standards and a consensus of validity.
- **Measurability** — at reasonable cost/benefit, adequately documented, updated regularly.

‘State’ vs ‘risk’ indicators

Ideally, there would be a single, straight-forward indicator of relative water quality. But there is not. Two main groups of indicators exist, and an effective evaluation of water quality involves the integration of both ‘state’ and ‘risk’ indicators (Parris 1997):

- **State** — The ‘state’ approach measures the existing concentration of constituents from agricultural activities, compares these to an allowable reference or baseline level.
- **Risk** — The ‘risk’ approach measures the ratio of *potential* contaminant to a tolerable or allowable level, based on a partial budgeting method of analysis.

State indicators

‘State’ indicators of water quality can be very difficult to establish, because water quality is such a complex area in which to derive indicators. There is a frequent lack of scientific knowledge or agreement as to how to interpret existing information. Also, water quality can vary considerably both spatially and temporally. Moreover, there is no easy way to isolate the contribution of agriculture, so they must often be estimated.

Chemical indicators

There is a well-established set of chemical indicators for monitoring the concentration or 'state' of agricultural pollutants in surface and groundwaters. These include the measurement of:

- **Oxygen** — dissolved (DO), biochemical demand (BOD), and chemical demand (COD).
- **Phosphorus** — total and dissolved (orthophosphate).
- **Nitrogen** — total, and dissolved (nitrate and ammonium).
- **Acidity** — in surface water.
- **Pesticides/heavy metals** — at very low concentrations.
- **Bacterial contamination** — faecal coliform and other pathogens.
- **Turbidity** — silt loading, often amidst considerable natural silt.
- **Salinity** — total dissolved solids.

The *Canadian Water Quality Guidelines* (1987 and updates) are an example of a 'state' indicator that relies heavily on a largely chemical guidelines approach to define acceptable water for drinking, recreation, irrigation, and other uses (CCREM 1987). The guidelines are based on documented studies of individual chemicals and represent a summary of research from Canada and elsewhere, considered applicable to Canadian conditions.

Recognising that there is no hard and fast line between good and poor water quality, maximum concentrations in the Canadian guidelines generally incorporate a safety factor at least 10-1 000 times greater than test results indicate. Hence the *Canadian Drinking Water Guidelines* state only that *continually* exceeding them "may, in some instances, be capable of inducing deleterious effects on health..." (FPSDW 1987).

Some view the Canadian (and similar) guidelines as the "far too liberal" approach to indicators of water quality. This is because any analysis of risk ultimately comes down to a matter of probabilities, and probabilities are usually based on historical data, assume average conditions, and project that past trends will continue. There is, however, often little historical data or trends from which to extrapolate the probable effects of trace agrichemicals on human life, and toxicology findings from laboratory rats may be far removed from people.

This uncertainty in assessment causes many people to favour a more stringent limit on guidelines, such as the threshold levels established in the *European Commission's 1980 Drinking Water Directive* (80/778/EEC) for:

- **Individual pesticides** — Maximum Admissible Concentration (MAC) is 0.1 µg/l.
- **Total pesticides** — combined MAC equals 0.5 µg/l.

- **Nitrate** — MAC 50 mg/l (25 mg/l reference level).
- **Phosphorus** — MAC 5000 µg/l (400 µg/l reference level).

From a cause/effect standpoint, it may not make sense to treat all pesticides the same, as though similar concentrations of different contaminants are equally harmful. Yet because of the uncertainty surrounding risk analysis, and for simplicity of definition, many favour the EEC guidelines.

Other ‘state’ indicators

Chemical indicators are only one way of evaluating the state of water quality and there is growing recognition that:

“The traditional emphasis on chemical indicators of water quality must be supplemented by more comprehensive indicators based on the total properties of a water body, including the physical, chemical, biological, radiological and ecological parameters of the water and of the material it carries” (Young *et al.* 1994).

The health of biologic communities can be an indirect indicator of the state of water quality. Biological indicators can be used to indicate the combined effects of pollutants, changes in habitat, and other impacts that chemical monitoring does not reveal. This is a complex task, however, relying on a science that is relatively new. Variations on this measurement include:

- **Species risk** — per cent of species at risk, dependent upon freshwater aquatic or marine habitats (having distinguished between imperilled and naturally rare species).
- **Biologic diversity** — diversity of species within the aquatic ecosystem.
- **Aquatic indicator species** — relative health of “most sensitive” species.
- **Ecosystem communities** — overall health and diversity of a group of species.
- **Functional diversity** — a sufficient range of species to perform the normal ecosystem functions of primary production, decomposition, etc.

Such assessments are an attempt to reflect the changes to biodiversity brought about by human activity. These assessments must also take into account the possibility of non-chemical effects from activities like fishing, hunting, altered stream flow, introduction of non-native species, reduced streamside vegetation, and climatic variation.

Other less developed indicators of the state of water quality might include:

- **Large population studies** — identifying “hard-to-detect” synergistic and additive effects by examining extremely large segments of a population.
- **Age relationships** — recognising that certain life stages (e.g. children, the aged) may be more susceptible or reflect consequences only evident later in life.

- **Watershed analysis** — conducting an overall assessment of ecosystem status within watershed boundaries.

Risk indicators

Indicators of risk are intended to provide an early warning of potential problems. This approach is preferred by some because of cost and the difficulty of establishing trends, and the limitations imposed by the use of state indicators.

Along with other countries (OECD 1994), Canada has recognised the need to develop “a core set of regionally-sensitive national indicators that build on and enhance the information base currently available on environmental conditions and trends related to primary agriculture...” (MacDonald and Spalding 1995). The Canadian project serves to illustrate the type of problem solving and range of work being conducted in other countries, though often by different means.

Box 1. Indicator of risk of water contamination by nitrogen (IROWC-N)

The first step (1) in IROWC-N analysis calculates the kg of nitrogen lost per hectares of land:

$$N \text{ lost (kg/ha)} = [(Residual \text{ N} \times P-PE)/(AWHC + P-PE)]/Area \quad (1)$$

This requires estimated inputs for:

Residual Nitrogen (N) — excess N (kg) remaining in the soil after harvest.

Excess Water (P-PE) — precipitation less potential evaporation (mm).

Average Water Holding Capacity (AWHC) — capacity for the soil to store water (mm).

Area — area (ha) supplied by water (e.g. ecodistrict).

The second step (2) is to calculate the estimated concentration of N in water (IROWC-N) and compare it to drinking water standards:

$$IROWC-N \text{ (mg/l)} = (N \text{ lost} \times 100)/(P-PE) \quad (2)$$

This final value for N is based on the assumption that:

Available residual N — the entire quantity of residual N is potentially available to leaching or runoff.

Constant soil N — though seasonally variable, soil N is assumed to be relatively constant over a 5-10 year period.

Denitrification — the entire quantity of N has not been lost (in the absence of denitrification estimates).

Manure N — availability of manure N (from cattle, for example) is 50 per cent in the year of application; 10 per cent carryover from the previous year.

Precipitation — the only input to the water balance; contributions from irrigation, the water table and capillary rise are ignored.

Source: MacDonald and Gleig 1996.

The Canadian approach to risk assessment in water quality is reflected in the development of an *Indicator of Risk of Water Contamination* (IROWC). This indicator is geared to examine major types of contaminants from agricultural activity such as nitrogen, phosphorus and pesticides. IROWC uses existing data on soils, crops and climate. It's spatial coverage ranges from a broad national view to detailed field level analysis. It does not rely on process models at the regional level, and temporal coverage can extend from seasons to decades. Current focus is at an ecodistrict level, measuring change over 5-10 year periods.

IROWC-N is the nitrogen (N) pilot of the Canadian indicator series (MacDonald and Gleig 1996), and is summarised in Box 1. Early test results using IROWC-N are encouraging. The indicator is sensitive to crop mix, fertiliser and manure application. Still, more work is needed on evaluating the probable effects of measures such as conservation tillage on N loadings, and there is a need to consider other N inputs/losses such as: atmospheric N, denitrification, and septic system leakage.

It is recognised that results of all such estimates must be carefully calibrated. In a 1-year mass balance analysis of N and P within 8 drainage basins in North Carolina and Virginia (McMahon and Woodside 1997), contributions from atmospheric N and P were comparable to those from fertiliser (27 per cent and 25 per cent, respectively), presenting “an especially difficult [mass balance] challenge.” In the end, researchers were uncertain as to the amount of excess agricultural nutrients that were available, due in large part to uncertainty about many of the factors required in a mass balance approach.

Other ‘risk’ indicators

A wide variety of other approaches to risk assessment within OECD countries are underway. Examples include estimates examining topics such as:

- **Sediment risk** — US, Australia.
- **Groundwater vulnerability** — US, Belgium, UK.
- **Core Pressure Indicators** — EUROSTAT.
- **Nutrient/pesticide balances** — Austria, France.
- **Cropping patterns/practices** — France, Germany.
- **Eutrophication risk** — The Netherlands.
- **Salinity risk** — Australia.
- **Runoff variability** — New Zealand.

5. Policy measures for water quality

Perception vs. reality

Public policy on water quality matters must address both perceived and real problems. Although scientists may think there is no serious agricultural pollution problem in an area:

The public's perception of agriculture's role in a clean and healthy environment is every bit as important as reality (MacAlpine and Nguyen 1993).

Verify the problem exists

It is incumbent upon government to clarify whether there is indeed a problem. For example, in the United States, sediment loading from agricultural lands is said to be "the most pervasive nonpoint pollutant" (Gomez 1995) and many people assume this condition must also apply to western Canada. But on a major river draining much of the Canadian prairies, silt loadings attributed to agricultural lands were deemed to be "relatively insignificant" when compared to those occurring naturally in base flow (Carson and Assoc. 1990). As well, the sight of grazing cattle crossing a stream is a highly visual effect and their impact on sediment loading is often assumed to be substantial. Yet work in a watershed deemed sensitive for its trout fishery (Sauchyn and Lemmen 1996), showed the relative effect on silt loading of the in-stream watering of range cattle was minimal compared to natural geologic loading.

Focus on "Hot Spots"

Where practical, efforts at monitoring and mitigating water quality should focus on existing and potential "hot spots" as early indicators of developing problems. These may be irrigated lands or sites adjacent to intensive livestock operations (ILOs), where difficulties could be experienced first. Problems could develop in these areas because of the intensity of the agriculture practised there and/or the nature of the soils and landscapes they often represent. In relation to agriculture in general, Hill *et al.* (1995) contend that people "need to get over the shock of low levels of herbicides being detected..." and focus attention on identifying those worst case scenarios where herbicide concentrations may occasionally approach limits in water quality guidelines.

Recognise social cost

There is a social (public) cost to pollution; and a "socially optimal" level of pollution control requires balancing the benefits of reduced levels of pollution with the costs of achieving them (Environment Bureau 1996). These benefits include: reduced environmental and human health damages; while costs (*opportunity costs*) encompass the lost value of goods and services required for pollution control.

On-farm/Off-farm costs

The on-farm effects of agricultural pollution might be reflected in reduced productivity, increased production costs, and on-farm health. Off-farm damages such as air and water pollution must, however, be borne by other sectors or by the public in general.

Some view concern over deteriorating water quality to be an indication that agricultural pollution is greater than some “socially optimal” level. The reasons why farmers may pollute above this perceived optimal level include:

- **Partial cost** — farmers are not required to pay the full social cost of the pollution they generate, leading to the selection of practices different from socially optimal choices.
- **Unaware** — farmers may be unaware of the adverse effect of their practices.
- **Reduce risk** — managers may feel that they must use higher levels of input to reduce production risk.
- **Low profits** — there may be few funds with which to make significant changes requiring large capital expenditure (e.g. moving a barn).
- **Beyond farmer control** — natural background levels of nutrients may already be abnormally high, or weather patterns may result in uncontrollable leaching and runoff.

Instruments of change

In the past, a type of moral persuasion has been used in OECD countries to promote environmental quality and sustainable agriculture (Huang and LeBlanc 1994). The objective has been to increase farmer awareness of potential contributions to environmental problems, and of potential best management practices to reduce those problems. However, such measures have met with limited success. This has led to interest in exploring alternative policy instruments.

Choosing selection criteria

The choice of the most appropriate policy instrument depends upon a number of criteria. The importance of each factor will depend on the specific environmental problem at hand. The use of but a single instrument may not be appropriate as there tends to be a trade-off among the criteria (Feather and Cooper 1995). And the final choice will not be purely objective, since it will unquestionably, be closely linked with the political process (Oskam 1994).

Specific criteria for selecting a policy instrument include (Environment Bureau 1996):

- **Environmentally effective** — controlling losses vs. controlling management practices.
- **Cost effective** — targeting pollution generating areas or times is preferred to uniformly applying policies.

- **Shared costs** — account for equity differences that may occur among existing operations, new entrants, industry sectors, regions, etc.
- **Politically and institutionally acceptable** — a good policy is an acceptable policy.
- **Jurisdictional authority** — relates to the scale of the problem, legal authority.
- **Consistency with government policies** — considers advantages of tax generation vs. subsidy expenditure; is market-responsive, non trade-distorting (GATT).

Choosing an instrument

Once an objective for environmental quality has been established, the next step is to choose the specific method or instrument likely to achieve that target.

A range of 17 instrument options have been identified that might be used to influence change in the actions of land and water resource managers (Stierna 1995). These options are listed in increasing order from “the least intrusive to greatest degree of intervention or control....” Stierna’s list provides a valuable insight into the scope of the options available and is given here in its entirety (Box 2), together with some possible applications for each option.

Box 2. Range of potential environmental instruments

- **Data collection and dissemination** — soil surveys, water quality indicators.
- **Research and research dissemination** — publications, risk assessments.
- **Technology development** — soil moisture probes, geopositioning technology.
- **Providing technical assistance** — reduced tillage, range improvement.
- **Credit availability** — animal waste systems, guarantee private sector credit.
- **Financial assistance and incentive payments** — cost sharing, tax credits.
- **Land retirement** — Conservation Reserve, permanent easements.
- **Quasi regulations** — linking program benefits to compliance.
- **Regulation** — feedlot siting rules, zoning land uses.
- **Management** — public lands and recreational areas.
- **Standards and criteria** — safe drinking water, highly erodible lands.
- **Training or sharing staff** — individuals or district staff, interagency training.
- **Certification and registration** — crop advisors, certified organic produce.
- **Demonstrations and education** — farm tours, school materials.
- **Promoting stewardship values** — advocating environmental stewardship.
- **Co-ordinated planning** — watershed planning, co-ordinated resource management.
- **Site specific planning** — BMPs for water quality, whole farm plans.

Source: Stierna, 1995.

Classification of instruments

A simplified classification places all environmental instruments into one of two main groups:

- **Command-and-control** — This has been the dominant method of controlling environmental degradation in many countries. It directly regulates the polluter to meet certain restrictions, and controls either the level of pollution or the type of farming activity that may be practised.
- **Incentive-based mechanisms** (economic instruments) — These mechanisms indirectly change farming actions through incentives to reduce the level of pollution-causing activity. They involve a voluntarily choice for change, and it is in a manager's best interest to do so.

Runge (1994) groups environmental instruments into 5 main categories that include what he calls 'carrots' (incentives) and 'sticks' (penalties):

- **Carrots** — a wide range of payments for environmental services including cost sharing, paid set-asides, easements, grants, positive tax-incentives, and soft loans.
- **Sticks** — include monetary fines and penalties, input taxes and charges, administrative charges, and civil and criminal penalties.
- **Conditionality** — incentives generally tied to pre-existing subsidies or programs, in which eligibility is conditional on adherence to environmental management practices.
- **Ecosystem and zonal management** — includes regulation, information and education, often in combination with the previous three instruments. An attempt to target particular ecosystems such as watersheds or areas susceptible to groundwater pollution.
- **Point-source intervention** — Typically focused on a specific facility, such as a livestock feedlot or food processing plant.

Economic instruments

Many believe it is necessary to increasingly integrate environmental and economic objectives in order to develop policies that will achieve sustainable development. Results from the application of environmental regulation to agriculture in the 1970s and 80s were generally disappointing. It was questionable whether the old command-and-control approach was working, particularly in regards to nonpoint-source pollution.

As part of a change in political thinking, largely due to fiscal constraints and changes in international trading rules (i.e. GATT) more and more countries have looked to the use of economic instruments. However, the application of economic incentives has been controversial, both amongst those advocating them as well as amongst affected interest groups and social scientists (Dubgaard 1991).

Advantages of economic instruments

There are clear advantages to the use of economic instruments. These include:

- **Lower cost** — the main advantage of economic instruments over other policy options is their ability to attain environmental objectives at lower cost. Economic incentives can do this because they are: **flexible** — do not impose the same level of pollution control across all firms, as typical of command-and-control; **specific** — encourage firms with low abatement costs to cut pollution levels, more so than firms with high abatement costs.
- **Stimulate new technology** — economic instruments provide incentives to develop and implement new pollution controlling practices because: **on-farm savings** — any resulting cost savings accrue directly to the firm; **save on taxes** — emission taxes can be minimised by reducing emission levels.
- **Reduced administration** — with economic instruments, costs may be lowered further since the administrative burden can be reduced: **farmer-choice** — allows firms to focus on the least-cost method of achieving goals; **fewer specifications** — eliminates expending government resources to certify technical options to achieve targets.
- **Accommodate growth** — economic instruments have the flexibility to accommodate growth and allow for the entry of new firms into the industry: **tradeable permits** — allow entering firms to acquire a permit from existing firms; **offsets remediation costs** — increased emissions taxes will reflect the cost of remediating increasing emissions.

Classification of instruments

Economic instruments have been classified by Segerson (1990) into what he calls *ex ante* and *ex post* definitions:

- **Ex ante mechanisms** — adjust price factors whereon firms make their decisions, some of which may cause pollution; e.g. taxes or subsidies on production practices.
- **Ex post mechanisms** — are enforced after the firm's decisions are made and only if pollutants are detected; e.g. assigning liability.

Another way of grouping economic instruments is through a *tax/non-tax* classification (Government of Canada 1992):

- **tax mechanism** — based on environmental charges and tax incentives;
- **non-tax mechanism** — includes tradeable permits, user charges, deposit-refund.

Tax on nitrogen — an example

An examination of environmental taxes on nitrogen helps to illustrate a few of the specific policies applied and the difficulties encountered in addressing this concern. Two principal types of N tax are: general and residual.

A general N tax: A general direct input tax on the use of N fertiliser has the advantage of simplicity of application — all lands and applicants are treated the same. Some have argued that the opportunity cost of N is not very elastic, and that large increases in N pricing (a tax on fertiliser purchase) will be required to discourage the marginal use of fertiliser N. But a preliminary study by Rainelli and Vermersch (1997) shows this is not so in the long term. Model results indicate that a tax on fertiliser N will result in a shift of resources from intensification (higher N use) to extensification (reduced N, more land and labour inputs). These steps towards extensification could be further enhanced by using nitrogen tax revenues to offset land and labour costs.

The disadvantages of a direct fertiliser tax are many and include (Huang and LeBlanc 1994):

- **Coarse estimates** — reliance on coarse estimates of cost: benefit.
- **Reduces profit** — is likely to directly reduce farm profit.
- **Penalises some crops** — those having a high N requirement.
- **Ignores N removed** — from the field when crops are harvested.
- **Soil/management differences** — does not account for soil, management differences.
- **Penalises efficient managers** — treats all management styles the same.
- **Penalises non-hazardous lands** — may tax lands unlikely to contribute to leaching.

Tax on residual N: A hybrid system of N taxation is based on the taxing of residual N (Huang and LeBlanc 1994). The concept proposes that farmers pay a simple tax for all N used, yet receive a tax credit for the amount of N harvested from the field, resulting in less residual N for leaching and runoff. The advantages to a residual N tax are:

- **Direct tax on excess N** — levied on N applied in excess of N removed.
- **Rewards management** — rewards farmers for removing N in excess of N applied.
- **Targets N polluters** — does not simply target all N users.

A recent preliminary study indicates that a significant incremental benefit to N reduction can come from the application of a small initial tax on residual N (Brouwer and Heming 1997).

There are, however, disadvantages to taxing residual N. Rewarding the removal of perceived “excess” N might well contribute to a loss in soil organic matter. Any resource incentive has its trade-offs and must ultimately affect not only management but other environmental considerations.

A mix of instruments

The increasing use of “Green Taxes” as an economic incentive is based on the concept that rather than using public expenditures to stimulate environmental change, applying public taxes is a more effective incentive. Such action has been seen by some as just another short-term technical ‘fix’ on the part of government, or a method that places too much faith in market forces to achieve the desired result (Andersen 1991). There is, accordingly, merit to a compound approach that involves a mix of environmental and economic instruments. These might include:

- **Voluntary measures** — intensified use of voluntary measures.
- **Economic instruments** — as an additional stimulus.
- **Agricultural extension** — a large-scale effort to communicate the benefits of change.

Cost a central factor

Where the costs of alternative instruments (e.g. nitrogen tax, quantity restrictions on fertiliser and leachate, and tradeable permits) are not substantially different, the desirability of each must hinge on factors other than cost (Thomas and Boisvert 1995). These might include the leaching hazard of individual soils or administrative feasibility. In the end, however:

“The cost efficiency of different measures and instruments to reduce nutrient loads should be a central criterion in deciding upon policy issue” (Sumelius 1994).

Institutional considerations

It is evident that the institutions through which green taxes are applied can have a great bearing on how they are perceived and their effectiveness. Andersen (1991) compared the “bureaucratic regulatory” (command-and-control) approach of agencies regulating pollution control in Denmark with what he considered a more “responsive” self-regulation through existing Dutch water boards. He warns that economists need to pay attention to the rules and institutions designed to implement green taxes, while recognising that command-and-control is not only economically but politically inefficient. Andersen says that:

“Green taxes should not be interpreted as a clear-cut alternative to rule-making, but as an instrument that can be employed as part of a more comprehensive regulatory mix of instruments” (Andersen 1991).

Other policy considerations

Need for proactive agriculture

The agriculture industry needs to continue its proactive role in reducing the potential to degrade water quality. Attention to environmental impact from agriculture will increase, and agriculture must be assertive in identifying and quantifying problems, taking action where needed:

“Denying that agriculture is having any impact will not be accepted. Agriculture must be proactive to avoid future regulation” (Hicks 1992).

Landowners must increasingly demonstrate that responsibility for land use and accountability for water quality go hand in hand with property rights (Wayland 1993). Society is spending billions annually to protect and restore the quality of rivers, lakes and streams. Critics acknowledge that the most sensible, cost-effective approach to water quality degradation may well be a reliance on the farm community to devise and implement pollution control. Yet they warn that increasing regulation is imminent and action is needed now (Offutt 1990). Still, in many countries the agricultural community has made significant advances toward reducing reliance on farm chemicals and decreasing potential impact on watercourses and groundwater systems. This progress needs to be emphasised, including the improvements in water quality associated with sustainable land management practices.

A multi-disciplinary approach

There is room for a more co-ordinated, multi-disciplinary approach to planning and monitoring of the effect of agriculture on water resources. We must find a common ground of understanding between opposing points of view. A balanced viewpoint on water quality concerns is needed by all parties — one that leads to informed debate amongst producers, special interest groups, politicians and the public at large.

6. Concluding remarks

Agriculture is affecting water quality within OECD countries, but a determination of its overall impact is a complicated and uncertain process. Opinions on water quality differ and are greatly influenced by different perceptions of acceptable risk. Water quality varies widely within OECD countries, yet is hard to generalise because of differences within and between countries, and the limited data available. Environmental indicators provide one option for monitoring the effects of agriculture on water quality. ‘State’ indicators measure existing levels of contaminants. ‘Risk’ indicators can provide an early warning of potential problems. The off-farm social costs of a loss in water quality must also be addressed. A variety of policy instruments exist to do so. Emphasis is increasingly focused on economic indicators as a means of coping with fiscal constraints while continuing to pursue environmental objectives. Agricultural policy needs to take a proactive role in addressing water quality concerns. A balanced, multi-disciplinary approach to water quality is required to more effectively address agriculture’s role in the management of this resource.

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WATER RESOURCE MANAGEMENT FOR SUSTAINABLE AGRICULTURE IN COASTAL AREAS

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1. Introduction

It is well known that irrigation may have detrimental effects in both soils and groundwater if specific measures have not been taken to confront them. This is particularly true when groundwater is the source for covering irrigation needs. The situation becomes even more critical when the underground aquifers are neighbouring the sea so that the fall of the water table (in unconfined aquifers) or the fall of the piezometric surfaces (in confined aquifers), may create intrusion into the aquifers. Under such circumstances a vicious circle of deterioration of both soils and groundwater may be established, which ultimately may lead to the annihilation of the irrigated agriculture.

Under natural conditions, the water balance of an aquifer may be written as:

$$D-R = -V$$

where,

D is the net water quantity feeding the aquifer,

R the net water quantity leaving the aquifer,

V the water retained in the aquifer and $-V$ its change.

If this water balance is expressed on an annual basis it is possible under natural conditions, the ingoing and outgoing water quantities to tend to become equal, so that $-V = 0$ and the aquifer water regime to reach a constant state expressed by given heights of the water table or of the piezometric surfaces. It is evident that any effort to exploit groundwater upsets the equilibrium conditions described above, so that its water balance may be written as

$$D-(R+M) = -V$$

12. The author is indebted to his research student, Mr P. Giannouloupoulos for helping him in preparing this report.

where M is the net water volume extracted by man. In this case, $-V$ takes negative values, i.e. the water retained in the aquifer is reduced and this reduction is expressed by a fall of the water table or of the piezometric surfaces. In the case where $(R+M)<D$, it is possible a new equilibrium state to be reached characterised by water volume retained $V'<V$ with M representing the safe yield of the aquifer. On the other hand, when $(R+M)>D$, the aquifer is gradually depleted of water and the water table or the piezometric surfaces may result in a reversion of the direction of the hydraulic gradient so that an inland sea water flow to be observed causing a degradation of groundwater quality.

It seems that the earliest description of sea water intrusion into the aquifers was given by Braithwaite (1855). It concerned sea water intrusion into the aquifers of London and Liverpool. Other early references to the phenomenon are those of Dubois (1905) and Pennink (1905), concerning sea water intrusion into the aquifers of the Netherlands. Since then the phenomenon has been observed in many countries all over the world. In Greece, sea water intrusion into the aquifers due to over-pumping is occurring with varying intensity in almost all the valleys neighbouring the sea of both the mainland and the islands where irrigated agriculture based on groundwater has been exercised. However, the phenomenon has been followed rather systematically only in the case of Argolid in Peloponese.

Various methods have been proposed (see Banks and Richter, 1953) for confronting sea water intrusion, such as the construction of artificial sub-surface barriers, the development by pumping of a trough of low water table or of low piezometric heights close to the coast, the development of a ridge of the water table or piezometric heights by recharging a line of wells parallel to the coast, by moving the pumping field inland further away from the coast and finally by applying artificial recharge of the aquifer with good quality water. Without entering into a detailed discussion of the effectiveness of the various methods proposed, one may note that only artificial recharge offers a possibility under favourable circumstances to solve the problem of sea water intrusion — overdraft by supplementing natural recharge with a recharge by artificial means. The methods used for applying artificial recharge may be distinguished in surface methods and underground ones (see, for example, Todd, 1959). The primary purpose of the first methods is to enlarge the area through which available water can infiltrate into the ground and extend the infiltration time. This is achieved, for example, by constructing low barriers (small dams) in the bed of existing water streams or by forming infiltration basins usually alongside existing streams where water can be conducted and left to infiltrate. These methods are used for recharging unconfined aquifers having a hydraulic connection with the flooded surfaces. Underground methods are mainly used for recharging confined aquifers, and involve already existing wells or bored-for-the-purpose ones penetrating into the aquifers to which clean water is injected to feed the aquifers directly.

It seems that one of the first attempts to apply artificial recharge through infiltration basins was made at Göteborg, in Sweden, in 1897 (Richert, 1900). Since then, and in particular after 1950, artificial recharge of aquifers has been applied in many countries all over the world to cover agricultural, industrial and domestic needs in good quality water. Thus in Sweden, artificial recharge has been intensified to become comparable with the natural recharge (Winqvist, and Merelius, 1970). In Holland the water supply systems of Amsterdam, Leyden and the Hague include infiltration basins at the coastal sand dunes to which water from the river Rhine is conducted and left to infiltrate at a rate of about $120 \times 10^6 \text{ m}^3$ per year. In Israel, artificial recharge involves $50 \times 10^6 \text{ m}^3$ per year (Zabludowski, 1970), while artificial recharge is applied extensively in many other countries in which the Czech Republic, Germany and the USA are included. In the latter country and more specifically in Long Island, more than 1 000 recharge wells have been drilled, constituting perhaps the most extensive recharge well field in the world, through which water is injected at a rate of $0.5 \times 10^6 \text{ m}^3$ per

day. In Greece, artificial recharge through wells has been applied in Argolid in 1964 for the first time being part of a more general plan, the main purpose of which was the rational use of water resources of the region in order to ensure the sustainability of its irrigated agriculture.

2. The case study of Argolid

Main characteristics of the region

The study which has been conducted covers the main Argolid plain, the valley of Assini-Drepanon, situated eastwards of the main plan and Iria valley, situated further eastwards (Figure 1). It started during 1962, to be continued, with some disruptions, to the present.

Figure 1. Location of the regions covered by research projects



The Argolid plain occupies the northern part of a geological depression formed between the mountain Arachneo to the east and the Arcadic mountain ridge to the west, both being limestone formation. The southern part of this depression is occupied by the sea, thus forming the Argolid bay. The formation of the plain has been reached through segmental rising of the land, which took place in previous geological eras, and transportation and deposition of sediments by the numerous streams, which flow or used to flow into the Argolid plain. Today, all these streams are ephemeral (winter streams) and, with the exception of Xerias and Inachos, the discharges of which may occasionally reach the sea, all other streams end at the outskirts of the plain where the water they transport is absorbed by the rather coarse sediments to recharge the underground water bearing formations. The total area enclosed by the watersheds of the Argolid is about 1 100 km², while the plain covers an area of 42 000 hectares, with a cultivated area of 29 500 hectares, out of which the 26 500 are considered to be suitable for irrigation. From the stratigraphical studies conducted, it has been found that the thickness of the sediments of the plain is variable and that at its centre exceeds 600 m. It has also been found that at the central-southern part of the plain, the sediments include three to five aquifers, sandwiched between clayey layers and that these aquifers at their outskirts are encircled by unconfined aquifers, the latter being mainly responsible for the recharge of the confined aquifers.

Further, it has been estimate that the annual natural recharge of the aquifers is on average of the order of $60 \times 10^6 \text{ m}^3$. The groundwater retained in these aquifers has been the main water source for covering the needs of the area. The region is endowed with a number of springs discharging water of very good quality, the most important of which are Lerni and Kefalari springs, located at the south-western edge of the plain. Lerni spring is a karstic overflowing spring, emerging at an elevation of 0.6 m above sea level and at a distance of 200 m from the seashore. Its discharges remain relatively constant throughout the year. Kefalari spring is also an overflowing karstic spring, emerging at an elevation of 24.3 m above sea level. Its discharges present a strong variability and are directly related to the precipitation regime. Further southwards from Lerni spring, there is a cluster of karstic springs, most of them emerging at the bottom of the sea close to the coast. Their discharges have been protected from the direct mixing with sea water by a coastal dam erected in the early 1970s. Their mean discharges are estimated to be of the order of $12 \text{ m}^3/\text{sec}$. It seems, however, that some mixing with sea water takes place underground, so that the water they discharge presents a chloride concentration ranging from 200 ppm to 700 ppm, with the highest concentration observed at the beginning of the autumn.

The Assini-Drepano valley is of an area of 900 hectares approximately. Quarterly alluvial deposits are encountered throughout the valley overlying a flysch formation. It is crossed by a small ephemeral river (Dafnopotamos) whose catchment is of an area of 54 km^2 approximately. Within the alluvial sediments (of a maximum thickness of 40 m) overlying the impermeable flysch formation an unconfined aquifer is developed. It is recharged directly from rainfall and indirectly by seepage from Dafnopotamos and it is discharged mainly through wells scattered throughout the valley. This aquifer constitutes the only source of fresh water of the valley.

Iria valley is located at a distance of 20 km south-east of Nafplion city and is of an area of about 1 300 hectares. It is run through by Karnazeikos torrent, with a watershed of approximately 200 km^2 , the erosive action of which is responsible for the formation of the valley. Significant springs do not exist in the valley and the only source of fresh water is groundwater retained in an unconfined aquifer developed in alluvial sediments. It is recharged by rainfall and by seepage from Karnazeikos torrent.

The expansion of the irrigated agriculture in Argolid and the degradation of its natural resources

Irrigated agriculture exercised in Argolid, has been mostly based on groundwater. Its expansion resulted in an over-exploitation of its groundwater resources followed by sea water intrusion into its aquifers. There is not accurate information concerning the expansion of the irrigated agriculture in the region. However, Table 1 contains estimations about this expansion through the years and about the increase of the irrigation water applied which may not differ substantially from the actual quantities involved.

Sea water intrusion into the aquifers was first recorded during the early 1960s, when groundwater as it was pumped from some wells showed an increase of concentration in chlorides, while signs of chloride toxicity, such as leaf burns and defoliations, particularly in citrus trees, were observed. Then the Ministry of Agriculture was alerted and it was decided a comprehensive research programme concerning the natural resources of Argolid should be initiated. Its purpose was not only to confront sea water intrusion, but also to ensure the future of an ever-expanding irrigated agriculture in the region. This general programme contained various sub-programmes for the spring water resources of the region (their regime and the quality of their water, their rational use for irrigation and artificial

Table 1. The expansion of irrigated area and the increase of the volume of irrigation water

Year	Irrigated area (ha)	Irrigation water applied $\text{m}^3 \times 10^6/\text{year}$	Contribution of various water sources		
			Groundwater	Kefalari-Lemi springs	Kiveri springs
1940	4 600	37	26	11	0
1965	12 500	100	80	20	0
1985	17 000	135	100	20	15
1995	21 000	150	115	20	15

recharge, etc.), for the hydrological characteristics of the ephemeral streams and, in particular, those of Inachos and Xerias, in an effort to retain their run-off and for the groundwater resources. In the latter sub-programme were included stratigraphical studies of the alluvial sediments of the region in order to localise their aquifers and determine their characteristics, the formation of networks of wells and borings for following their water level and obtaining groundwater samples, the insertion of piezometres in the aquifers accounted during the stratigraphical works, the application on an experimental basis of artificial recharge through existing wells, the execution of pumping tests for determining the hydraulic properties of the aquifers etc. The research programme was initiated during 1963, and lasted for four years. Thus, valuable information about the water and soil resources of the region was collected which could help in forming a plan for their rational use for a sustainable agriculture. Details of the general programme and its progress were given in a report by Stasinopoulos and Poulouvasilis (1965).

As has already been mentioned, experiments of artificial recharge of the aquifers started during 1964. For this good quality water from Kefalari spring was transported to the eastern part of Argolid and was injected into existing wells in irrigated areas close to Nafplion city and in Assini-Drepano valley where the most severe symptoms of chloride toxicity were observed. The experiments continued up to 1967 and involved a volume of water injected of about $1\,000\,000\text{ m}^3$ per recharge period (winter and early spring). These experimental recharge efforts resulted in a substantial improvement of groundwater locally, accompanied by the recovery of the affected citrus plantations. Based on the results of these experiments, the Ministry of Agriculture decided that artificial recharge ought to be applied on a large scale using the winter and early spring discharges of a volume of about $40 \times 10^6 \text{ m}^3/\text{year}$ in order to confront sea water intrusion and supplement the natural recharge of the aquifers. Unfortunately the research programme came to a halt during 1967, although some piezometric measurements and groundwater analysis and some local efforts for recharging were continued during the 1970s. Research efforts re-started after 1985 in the frame of a new research project funded by the Ministry of Agriculture and later by the EU and conducted under the responsibility of the staff of the Laboratory of Agricultural Hydraulics of the Agricultural University of Athens, in collaboration with the staff of the local unit of the Ministry of Agriculture. In the frame of these projects artificial recharge re-started during 1990.

The progress of sea water intrusion through the years varied from region to region according to the water-holding capacity of the aquifers, the characteristics of their natural replenishment, the pumping intensity and pattern, the permeability of the aquifers and finally the availability of other water sources which could be used for irrigation or artificial recharge. Thus, in Argolid plain where the overdraft continued to increase through the years, the advance of the salinisation front obliged the

farmers to abandon their affected wells and to open new ones farther away from the coast or to buy irrigation water from their northern neighbours. In this way, the pumping fields moved gradually inland towards the central and northern part of the plain. This inland movement moderated, perhaps, the salinisation process, but, of course, did not prevent the descent of the piezometric surfaces and water tables in the central and northern part of the plain. This fall obliged the farmers to deepen their boreholes or drill new ones penetrating deeper layers, so that in many cases they had to pump water from a depth of 200 metres. There was a progress in salinisation of groundwater over the period 1963-90 and, further, a dramatic fall of the piezometric surfaces which, in some cases, was of the order of 100 metres, so that many boreholes were dried up. The serious shortage of water observed during the late 1980s led to the application of the artificial recharge and the use for irrigation of Kiveri water. For the recharge was used water from Kefalari spring, which was transported to the southern part of the plain through the existing Nea Kios canal and was injected in neighbouring boreholes. After the construction of the Kiveri canal in 1994, Kefalari water could be transported into the central part of the plain by free flow and the recharging front moved northwards. The volume of injected water during the interval 1990-96 is shown in Table 2.

Table 2. Water volume applied for artificial recharge from 1990–1996

Year	$\times 10^6 \text{ m}^3$
1990	3.09
1991	6.92
1992	5.68
1993	3.89
1994	14.00
1995	13.59
1996	7.22
TOTAL	54.39

It must be noted that recharge water was injected into the borings simply by siphoning it from the Kiveri canal. A substantial reduction of salinity had occurred over the 1990-96 period, as well as a substantial ascend of piezometric surfaces, particularly in the central and northern parts of the plain. This improvement must, at least partially, be attributed to the artificial recharge applied since the pumping rate was not reduced during that time interval. It may be noted that the principal direction of flow of recharge water was towards the trough of the low hydraulic heads prevailing in the northern part of the plain following the hydraulic gradient established in the process of recharging. The salt content of the upper soil layers during the interval 1963-96 remained rather small, but it showed an increase with depth, particularly in the low southern areas of the plain where high water tables prevail and Kiveri water has been used for irrigation. Salt balances in the soil profile have been followed, from which it has been concluded that the salts are washed out of the upper soil layers under the combined action of rainfall and irrigation water applied.

In the case of Assini-Drepano valley, the deterioration of groundwater quality has been more or less checked mainly because artificial recharge of its aquifer with Kefalari water has been continued, with some interruptions, from 1964 onwards. For the years 1990-93 the injected recharge water varied between $0.6\text{--}10^6 \text{ m}^3/\text{year}$. A substantial improvement of the groundwater quality has been attained from 1962 to 1993 which allowed even the sensitive to chloride plants such as citrus to have a satisfactory productivity.

In Iria valley the quality of both soils and groundwater continued to deteriorate through the years. In this case water could not be transported from the Argolid plain to be used either for irrigation or artificial recharge in Iria valley due to the large distances involved, so that the only source for irrigation water was groundwater. In 1993, the chloride content of groundwater and in general its salt content was so high that it could not be used for irrigation. However, groundwater has been used for irrigation through the years so that the citrus plantations of the valley have been exterminated. Today, some vegetables such as lettuces and artichokes with a growing period during winter and spring can survive in the valley, taking advantage of the rainfall occurring during winter and spring.

The strategies for meeting irrigation demands of Argolid

If it is supposed that irrigated agriculture will further expand in the near future to cover 24 000 hectares, then it may be estimated that the total volume of irrigation water needed would be in the order of $200 \times 10^6 \text{ m}^3/\text{year}$ and that the mean specific discharge required during the critical summer months for the whole irrigated area would be around $17 \text{ m}^3/\text{sec}$. In order to meet the above one needs, two strategies have been developed over the years. The first one considers as main source of irrigation water the discharges of Kiveri springs. For this, a pumping station has been installed close to the springs to pump water into the Kiveri canal. Further, a number of pumping stations will be installed along this canal to transport water to higher elevations into excavated ponds. Finally, the water retained in these ponds will be pumped into an underground irrigation network consisting of pipes and covering the whole plain. It is evident that the completion of this irrigation water delivery system demands an enormous funding, but apart from this the plan suffers from some rather serious disadvantages. Thus, the rather high chloride concentrations of Kiveri water may have detrimental effects on the productivity of the plantations, particularly those consisting of citrus trees. Moreover, the indiscriminate use of Kiveri water may cause serious quality deterioration of both soils and groundwater. If it is supposed that $150 \times 10^6 \text{ m}^3/\text{year}$ is used for irrigation, it comes out that 70-90 metric tones of NaCl will be deposited on the irrigated soils each year or about 3 000 kg/ha/year. If this salt load were to remain in the soils the latter will be salinised in some years' time. Therefore it would be necessary for this salt load to be washed out of the soil profile and eventually reach groundwater causing a serious deterioration of its quality, particularly in those areas where unconfined aquifers are developed which constitute more than two-thirds of the whole plain. Further, the discontinuation of the pumping regime will cause a gradual ascend of the water table, the control of which would necessitate the installation of a drainage system all over the plain. Finally, since the recharge of the Kiveri springs during the critical summer months is not so big as to cover irrigation needs, another water source with a capacity of about $5 \text{ m}^3/\text{sec}$. will be needed. Groundwater could cover these needs if its quality were to remain good enough, which is very doubtful since it would be polluted by irrigation leachates.

The second strategy considers as main source for irrigation water groundwater after supplementing its natural recharge by an artificial one. For this winter and early spring discharges of springs, mainly those of Kefalari which can be transported into the plain by free flow, could be used. Today these discharges, exceeding $40 \times 10^6 \text{ m}^3/\text{year}$, flow directly to the sea. It is estimated that groundwater can provide for irrigation a volume of water of about $100 \times 10^6 \text{ m}^3/\text{year}$ if artificial recharge is properly applied. Lerni and Kefalari discharges during the irrigation period could provide $25 \times 10^6 \text{ m}^3$ approximately, per year while the remaining $75 \times 10^6 \text{ m}^3/\text{year}$ needed could be obtained from Kiveri springs to be used for irrigation of soils overlying impermeable clayey layers in the Argolid plain and those where groundwater is unsuitable for irrigation as, for example, in Iria valley. The two strategies have been well known for many years to those Greek authorities responsible for deciding on such

matters, but up to now they have been unable for various reasons to adopt the proper one and implement it.

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OFFICIAL STATEMENT

by His Excellency, Stefanos Tzoumakas, Minister of Agriculture, Athens, Greece

The management and protection of water resources, aiming at their preservation for the generations to come and more specifically their integration to the government policy for the sustainable agricultural development in Greece, is a concern of paramount importance to the Greek Government.

Greece is a typical Mediterranean country and it presents uneven precipitation distribution in various areas. Water deficiency is often observed during the summer period (July-August). Collective and individual irrigation works are under construction to cover the needs in water; those works usually involve high construction costs. During the last years, the importance of water resources, along with technical information on the use of water in agriculture, have been incorporated in the professional training of farmers, aiming at the best use of irrigation.

At the same time, a national policy has been established for the protection of the quality and quantity of water resources. Observation of water quality is monitored through measurement and analysis of the surface and ground water resources used in agriculture, to identify pollution sources and to take appropriate measures for their elimination.

The greatest problem of water resource management in Greece is the quantity of water.

The quality of water resources in our country is generally good, with limited exceptions due to local conditions.

The most important water quality problem in our country is related to sea water intrusion, which is caused by large-scale water pumping. Efforts are being made to improve this situation to prevent negative effects on agricultural development.

This workshop is of interest to our country, because it will contribute considerably to our efforts in defining new, much needed policies which will secure the sustainability of water resources. In this framework, your work is very important for the development of indicators which define the relationship between agriculture and environment in relation to quantity, which is of great interest to Greece and in general to our agriculture, as well as quality, which we constantly monitor to avoid the problems that other developed countries have encountered.

The Greek Government looks forward to hearing the results of this workshop.

With these thoughts, I declare the workshop open, and hope for a successful outcome.

OFFICIAL STATEMENT

by Gérard Viatte, Director for Food, Agriculture and Fisheries, OECD Paris, France

I wish first of all to thank our Greek hosts most warmly for the very active role they have played in preparing and organising this OECD Workshop on the Sustainable Management of Water in Agriculture. I should also like to thank the eight financial contributors: Canada, the European Commission, Finland, France, Japan, Spain, Switzerland and the United States. The organisation of this Workshop could not have been possible without their generosity.

The work of participants in the two meetings of the Steering Group for the Workshop has been most valuable, notably in selecting the main themes for the Workshop. I want to make a special mention to countries which have prepared case studies and to consultants who have contributed to guide our thinking on the interface between agriculture, water and the environment. I also wish to welcome the participation of international organisations, environmental NGOs and farmers' professional organisations who will certainly enrich the dialogue on this important area. I want to express my appreciation to all of you who are here today: your participation augurs well for the coming discussions, and I am sure the Workshop will benefit from your broad range of experience, both national and international. The considerable interest raised by the theme of the Workshop is a pointer, I hope, to the success of the proceedings on which we are about to embark.

How the Workshop fits in with the OECD work on agriculture and the environment

Work in the OECD in recent years on agriculture and the environment has been largely undertaken through the Joint Working Party of the Committee for Agriculture and the Environment Policy Committee (JWP). The work of the JWP is undertaken within the broad directions provided by the Committee for Agriculture, in particular the reform of agricultural policies, and by the Environment Policy Committee whose work includes several issues which concern the agricultural sector. The overall aim of the JWP work is to identify and analyse ways in which governments might promote market solutions and design and implement policies to achieve environmentally, economically and socially sustainable agriculture at minimal resource cost to the economy and with least trade distortion. In working towards this aim, activities have focused on the conceptual and empirical analysis of the effects of agricultural policies and policy reform on the environment; the effects of environmental policies on agriculture; and the development of quantitative tools, especially indicators.

Work has shown that there are both positive and negative environmental effects of agriculture, that a greater emphasis is being placed on environmental issues in agricultural policy in OECD countries,

that agricultural policy reforms have tended to benefit the environment, but that policy reform will often not be sufficient to improve the environmental performance of agriculture. Environmental performance will be improved if policy measures and markets do not give conflicting signals to farmers. Some policy measures addressing the environment are not sufficiently transparent in their objectives or sufficiently well targeted to environmental outcomes or tailored to particular environmental situations. There is therefore a need for more quantitative information on the linkages between agriculture and the environment. The effects of measures to improve the environmental performance have also sometimes been compromised when they have been implemented together with market price support policies.

The Workshop is an integral part of the programme of work of the JWP. It marks the beginning of the JWP reflection on the interface between agriculture, water and the environment in the agricultural policy reform context on the one hand, and as part of natural resource management on the other hand. This activity introduces a new element into OECD work in analysing agricultural policies, including the agri-environmental dimension. The broad issue of sustainable development is one of the focal points underpinning the future activities of the OECD. The Secretary-General, Mr. Donald Johnston, allows personally a very high priority to this objective. Moreover, it is very opportune, given that water is moving up the agenda of policy makers. For example, "Strategic Approaches to Freshwater Management" will be the main theme of the programme of work of the UN Commission on Sustainable Development for 1998 -- a year also in which the French authorities will organise an International Conference on Water and Sustainable Development. For the information of participants, the Secretariat has prepared a brief résumé of past and present OECD activities on water, which include references to agriculture (see Annex).

What is the expected outcome of the Workshop?

A key objective for this Workshop is to understand the linkages between policies in the fields of agriculture, water and the environment and to help policy makers in trying to achieve sustainable management of water in agriculture. It is important to be aware of the progress made, particularly in recent years, towards agricultural policy reform commitments in OECD countries. The long-term benefits of reform are beginning to emerge, but with the increasing complexity and variety of agricultural policy measures, more effort is required to fully evaluate their environmental impacts.

Lowering output-related support, such as price support and farm input subsidies, tends to reduce domestic price distortions and border protection, with consequences on farm practices, the type of commodities produced, and the location of agricultural production, which in turn impact on water use and water quality. Policy reform will also improve resource allocation -- thus reducing some of the environmental pressures, such as the depletion of water resources and the pollution of water -- although this also crucially depends on the existence of markets, or other institutional mechanisms, and on technical progress. Such policy measures can contribute to slow down or bring to a halt the conversion of environmentally fragile or ecologically valuable land to agricultural uses.

Considering water as an input, more thought is needed on the issue of the costs and benefits of supplying water to agriculture. The "public good" nature of major water supply facilities, dams or drainage schemes -- including their functions for landscape, water conservation, prevention of flooding and tourism development -- explains that their creation, operation and maintenance are traditionally financed by taxpayers. However, in the use of irrigation water, agriculture cannot claim special privileges, such as preferential consumption charges, or subsidised provision of on-farm

facilities. The concept of full recovery of the economic costs of supplying irrigation water deserves more attention.

Considering water as an environmental good, it is important to determine if there is a need for policy measures to complement the effects of agricultural policy reform on water resources and, if appropriate, to define the conditions under which such measures are going to be effective. Many countries have already attached environmental conditions to policies that deliver support to farmers or have introduced incentives or, to a lesser extent, have imposed constraints for environmental conservation. Agri-environmental measures appear to have been effective when the environmental objectives are clearly specified and measures tailored to the environmental, economic and social situation prevailing in a given area. The Workshop should evaluate to what extent water quality or water quantity objectives have been given enough and specific attention in formulating the agri-environmental measures and, as appropriate, if the arrangements are compatible with the polluter-pays-principle.

Concluding remarks

The OECD has agreed to the reform of agricultural policies, and to the sustainable management of natural resources. The results of this Workshop should provide a valuable contribution to the policy debate in the OECD, in a forward-looking perspective. This could be achieved by:

- developing a better understanding of the policy issues related to agricultural water use and the pollution of water originating from agriculture;
- recognising the need for a coherent approach to agricultural, environmental and water policies toward achieving sustainable water management in agriculture;
- providing a critical assessment of the policy measures currently used for the enhancement of such policy coherence through the analysis of case studies;
- analysing the impact on water use and water quality of agricultural policy reform efforts toward more market orientation of agricultural production;
- helping to identify if and where there is a need for appropriate, targeted policy measures to complement agricultural policy reform, and, as appropriate, the best policy mix (regulations, economic instruments, voluntary schemes);
- defining the conditions under which the principle of full cost recovery can be applied in the formation of water prices in agriculture, and the role of markets;
- outlining the institutional framework, and the role of public and private sectors to promote sustainable water management in agriculture;
- contributing additional work on agri-environmental indicators to agree on specific indicators and methods of measurement of the impact of agriculture on water use and water quality.

To conclude, I wish the Workshop all success. I trust that the discussions will be lively and fruitful, and that the Workshop will help to provide a number of useful signposts and pointers for the analysis and development of policy relating to the interface between agriculture, water and the environment.

ANNEX

OECD publications in the area of water, agriculture and the environment

OECD publications in the area of water policy

The first analysis by the OECD of issues related to water projects dates back from 1970 when a study on irrigation policies was carried out in the six OECD Mediterranean countries and the United States. Drawing on the conclusions of this study, the OECD organised a Seminar, here in Athens, in 1971 to consider two main subjects: the economic evaluation of irrigation projects as a means of improving their profitability and, a concerted policy for the development of irrigation. This led to the publication in 1973 of a *Guide to the Economic Evaluation of Irrigation Projects*. In 1985, the OECD published the *Management of Water Projects: Decision-Making and Investment Appraisal*, which covers a broader spectrum than just irrigation and takes account of the effects of water management on the environment. It analysed the factors to be taken into account for decision-making and appraisal in large-scale investment projects in the field of water management.

The outcome of more than a decade of co-operation by experts in OECD countries on water quality issues led to the publication, in 1982, of the *Eutrophication of Waters: Monitoring, Assessment and Control*, which describes the complexity of this phenomenon and the factors in its development, and points to the most effective means of control. In 1986, the OECD published *Water Pollution by Fertilisers and Pesticides*, which argues that changes in agricultural practices are necessary to limit the environmental costs to society and discusses policies that could be adopted by Member countries.

The OECD's first survey of water pricing policies was published in 1987. The *Pricing of Water Services* put forward options for economically rational pricing practices which would lead to environmental improvements. It focused mainly on the pricing of water to industrial and household users, though it briefly considered the pricing of irrigation water. In 1989, the OECD publication on *Water Resource Management: Integrated Policies* underlined the need for more effective policy integration within the water sector itself and vis-à-vis other economic sectors having a major impact on water resources. The 1989 OECD Council Recommendation on Water Resource Management provides guidelines for policy-makers on strengthening institutional arrangements, improving water demand management and protecting groundwater resources.

Since 1995, the Co-operative Research Programme on Biological Resource Management for Sustainable Agricultural Systems has included a theme on "Water Quality and Agricultural Practices". Fundamental scientific research is sponsored -- by means of an annual fellowship programme and the organisation of international workshops -- on numerous topics related to water quality: fertiliser and pesticide use and water quality; the impact of animal waste and soil erosion on water quality; the transmission of human, animal and plant pathogens in surface water and irrigation systems; detection methods for chemical and biological trace components; and, modelling of water quality.

As part of the OECD Programme on Sustainable Consumption and Production, an Experts Workshop on Sustainable Water Consumption was held in Sydney, Australia, on 10-12 February 1997. The proceedings are in the process of being prepared for publication. The Workshop examined policy options to improve the sustainability of water consumption in the agricultural, industrial and commercial/residential sectors, and to more effectively manage demand between competing uses, including the water needs of the environment. Countries are increasingly recognising, and acting on, the need for integrated water cycle management, considering both production and demand side pressures. There is a need to develop an appropriate institutional framework; establish water pricing regimes that reflect the full costs of supplying water, preserve water quality and maintain the resource base; strengthen education, information and partnership strategies to modify user behaviour; and promote a wider diffusion of water efficient technologies. Greater involvement of water users, including private sector firms and communities, is also a critical element for the sustainable management of water resources.

As part of the OECD work on Subsidies and the Environment, a survey of water subsidies in OECD countries is being undertaken with the aim of identifying subsidies that have adverse impacts on the environment. The project will encompass water subsidies (and tax incentives) to energy, transport and agriculture.

OECD publications related to the interface between agriculture and the environment

Some of the results of the JWP work have already been (or are being) published. Publications have appeared on *Sustainable Agriculture: Concepts, Issues and Policies* (1995), *Environmental Indicators for Agriculture* (1997), *The Environmental Effects of Agricultural Land Diversion Schemes* (1997), *Agriculture, Pesticides and the Environment: Policy Options* (1997). A consultant paper on *Agriculture, Trade and the Environment: Anticipating the Policy Challenges* was just made available on general distribution. A publication on the *Co-operative Approaches to Sustainable Agriculture* is forthcoming and other work is planned for publication in the near future: *The Environmental Effects of Reforming Agricultural Policies: a Preliminary Report* and *Agriculture and the Environment: Issues and Policies*, a synthesis report of the JWP work since its inception.

This Workshop is the third organised under the aegis of the JWP. The proceedings of the Workshops held in Madrid, in 1994, and in Helsinki, in 1996, have been published under the titles *Forestry, Agriculture and the Environment* (1995) and *Environmental Benefits from Agriculture: Issues and Policies* (1997). Another Workshop will be held in 1998 in the United Kingdom on agri-environmental indicators.

SUMMARIES OF THE CASE STUDIES ON POLICY MEASURES TOWARDS A SUSTAINABLE MANAGEMENT OF WATER IN AGRICULTURE

1. Australia: A strategic framework for the reform of Australia's water industry

Of the annual estimated 14.6 km³ of water used in Australia (based on a 1983-84 survey), 70 per cent is used for irrigated agriculture with a production value of about A\$ 6 billion (US\$4.5 billion). This represents 25 per cent of all of Australia's agricultural production. It is fundamental to the long-term future of Australia's irrigated agricultural industry, and the socio-economic regions that it supports, that water resources are managed in an ecologically sustainable manner. This means that water is managed to ensure both adequacy and security of supply as well as water quality sufficient to meet the full range of beneficial uses. A key policy objective of Australia's governments is thus to bring about a more efficient, equitable and sustainable management of the nation's water resources.

Australia's federal system of government poses a number of challenges and opportunities in developing water policies. The six States and two Territories have the prime constitutional responsibility for natural resource management which could lead to fragmented approaches. However, all of the nation's governments have recognised the need to work together in developing a major national integrated framework for the efficient and sustainable reform of Australia's water industry.

The Council of Australian Government's (COAG) Framework for the strategic reform of Australia's water industry comprises a package of diverse but interrelated measures intended to generate an economically sustainable water industry, with improved outcomes in terms of sustainability of natural resource use, as well as better environmental outcomes. The Framework is designed to ensure that there is a consistency of approaches across the nation. At the same time it allows the flexibility for each jurisdiction to adopt its own approach to implementation, depending on its own institutional and natural characteristics. Because of this flexibility, the COAG Framework (developed to meet the unique requirements of the Australian federal system) could be useful as a generic model for other OECD countries.

The Framework: i) Covers both rural and urban areas and addresses a range of issues including environmental issues, pressures associated with population expansion, and the need to ensure the viability of food production industries. ii) Responds to the need for integrated approaches across a range of issues, with a comprehensive package of interrelated measures which together will help ensure that water resources are managed in more efficient and sustainable ways. iii) Recognises the importance of effort at national, provincial and local/catchment levels and the important and unique contribution that each level can make. The reform programme provides an essential strategic national direction, which at the same time takes into account the technical and policy diversity across provincial or State governments. iv) Emphasises the importance of community involvement in working through detailed responses to the COAG reforms, as well as in local "on the ground" activities (e.g. in contributing to integrated catchment management approaches).

The Framework measures interact to address market failures and adjust the institutional framework within which water resources are delivered and used. The aim is to encourage the private individuals who make up the irrigated agriculture industry to use those water resources more sustainably and productively. Through the Framework farmers are offered real benefits in terms of a more secure livelihood, as well as opportunities to exercise much greater control over their own business affairs. This has become a powerful incentive for change at the irrigation district and farm levels.

The challenge is to apply full economic cost recovery principles to water pricing in rural areas by 2001 notwithstanding the difficulties in adopting the economic approach to charging. Approaches to implementation in New South Wales and Queensland provides an indication of the practical considerations of dealing with the policy requirements.

2. Austria: Water protection within the Austrian agri-environmental programme

Since the beginning of the 90's, Austria has taken important steps to reduce water pollution by agriculture, in particular by granting subsidies to farmers. The accession to the EU has intensified this type of approach. The "Environmental Programme for Austria" (ÖPUL) was introduced in 1995 on the basis of EC Regulation 2078/92. About 25 measures are aimed at soil, air and, in particular, water protection, within a programme based on voluntary participation.

A level of participation of 80 per cent was achieved. Some measures encourage farmers to farm according to methods particularly beneficial for the preservation of water quality. The three following criteria must be fulfilled: renouncing to, or reducing the application of fertiliser and plant protection products; complying with a maximum limit for livestock densities; and applying a crop rotation system with greencovering.

The main eligibility criterias for the ÖPUL are a combination of different measures. Only some parts of the programme are relevant to water quality in agriculture. These include: maximum of two livestock units per hectare of productive land; maintaining the share of grassland area; complying with the recommendations of the technical advisory board for land fertility and land protection; maintaining existing elements of the landscape; observance of organic farming methods in accordance with EC Regulation 2092/91 and national regulation concerning livestock keeping on organic farms; ban of application of easily soluble fertilisers; ban of application of synthetic pesticides in accordance with EC Regulation 2092/91; maximum of 75 per cent of cereals and maize; period of 3 months minimum between sowing of green cover and ploughing; planting of cereals, maize, soyabean and sugarbeet by way of mulching and underseed in maize; conversion feeding on maize to natural grazing; conversion from maize to grassland.

3. Canada: Water use and water quality in agriculture — Canada's national policies

Since the formation of Canada's Federal Water Policy ten years ago, water is becoming an increasingly important environmental issue, particularly as it relates to the agriculture and agri-food sector. The federal and provincial governments implement the policy through a number of short term programmes and, to a lesser extent, permanent programmes, which are intended to improve the sector's environmental performance and reduce its impact on water resources.

These programmes are primarily based on voluntary approaches relying on information and incentives. In a few cases, they also include a number of economic instruments and more stringent

regulations. Together, these initiatives have led to significant improvements in the efficiency of water use and reductions on the impact of agriculture on water.

A number of changes are occurring inside and outside the agriculture sector which will affect the way Canada's agriculture sector addresses environmental issues in the future. These changes include significant increases in agricultural production and processing; opportunities for Green Marketing; increasing public pressure on the sector to reduce its impact on water resources; and, decreased levels of funding for government programmes.

Given the effectiveness of previous programmes and the agriculture sector's proactive stance, the Committee in charge of updating the Federal Water Policy has concluded that no major changes to the policy statements related to agriculture are required. It is clear, however, that government and the sector must modify their approach if they are to continue to effectively implement the policy in the future. While voluntarism will continue to play a role, insufficient funding precludes incentive-based programmes. The sector must expand the application of economic-based instruments which can be sustained over the long term without generous government funding. This fact has been recognised and progress is being made on developing some new economic-based instruments.

4. France: Partnership between the agricultural community and the basin's agencies (Adour—Garonne)

In the Adour-Garonne Basin, in the south-west of France, agriculture represents a growing share of the region's general economy. This has affected the quality and the quantity of water in a Basin well provided with water, but where levels are extremely low from the end of spring onwards. Thirty per cent of the Basin area is considered as sensitive with regard to pollution by nitrates and eutrophication of rivers. Similarly, water drawn for irrigation "creates a deficit" of 300 million m³ to the hydrological balance.

Although representatives of the agricultural community have been associated with the work of the Basin's Agencies since their creation, it is only very recently that they have become aware of the need to be more proactive within these bodies in order to contribute to water conservation and protection.

The master plan for water development and management (SDAGE) recently implemented by the Adour-Garonne Basin Committee prescribes several measures to correct the adverse effects of agricultural practices on water. The SDAGE has paved the way for a framework agreement with farmers. The framework agreement stipulates both taxes and financial aids involved in a contractual partnership for the next 5 years (1997-2001).

The "drawing" tax, applies to all hectares irrigated over and above a threshold of 5 000 m³/year. The rate of the tax remains unchanged for 5 years if the volumes drawn are metered, but rates increase each year if based on an initial flat fee calculated in accordance with a formula provided in the framework agreement. Two rates have been introduced: a basic rate for underground water, hill lakes, and rivers which are not refilled artificially, and a higher rate for artificially refilled water courses. The "pollution" tax will be implemented where livestock farmers do not respect a schedule for the standardisation of waste water.

To supplement farmers' financial contribution, the Water Agency is contributing FF 235 million (US\$40 million) for the 5 years, towards total project costs, estimated at FF 745 million (US\$128 million) (excluding the creation of new reserves). The aid programmes are wide-ranging

and include: i) the relaunching of the water resources development programme; ii) the increased participation of farmers in collective management of the water resources, together with encouragement to measure the use (meters), save (irrigation in particular), and protect water; iii) the involvement of farmers in the planning and maintenance of river flow; iv) the setting up and monitoring of a programme of pollution reduction based on improved cultivation practices and the control of farm and wine cellar pollution; v) the implementation of the programme to eliminate mud through agriculture; vi) the recuperation and treatment of toxic agricultural waste; and vii) information programmes.

Through its system of differentiated taxes, the Agency is emphasising the obligation to meter water used for irrigation and the resulting savings in water use. The higher charges for refilled rivers justify the use of public funds to restore water levels adversely affected by farming practices.

Through its expanded aid programme, the Agency is demonstrating its concern for all aspects of farming and thus most of the Basin's 200 000 farms are involved. The adherence of agricultural representatives to this framework agreement should not hide the reservations and hesitations of certain farmers that the Agency must endeavour to overcome through appropriate communications strategies.

5. France: An incentive policy for sustainable management of irrigation water in the Loire-Brittany basin

Water resources are increasingly threatened, parallel to the development of the economy. The sustainable management of water resources, essential for the maintenance of these activities, requires more discipline in the use of water.

Even in northern Europe where there is an apparent abundance of water, a succession of dry years, coupled with a huge growth in the demand for water, may cause a serious unbalance with shortages and a crisis management.

Economic and statutory tools, some of which are provided for by the latest Water Act of 3 January 1992, have to be put in place to ensure the offer meets the demand with regard to the natural environment, and that water resources are maintained for next generations.

In the Loire-Brittany basin, which covers a third of France's territory, the development of intensive irrigation constitutes the essential factor of unbalance, particularly for underground waters. The master plan for water development and management of water (SDAGE) of this basin and the Water Agency's own programme have made the improvement in the management of water resource their *main* objective. A strategy in 6 parts has been decided to reach this objective: knowledge of volumes withdrawn; knowledge of available resources; satisfying the needs of aquatic environment (minimal river flow); volumetric management of withdrawals; water saving; and tariff concessions.

The Water Agency, following the *user-pays* principle, has put in place, an incentive policy (based on payments and taxes) to encourage farmers to carefully manage their irrigation water. In particular, an original pricing policy was set up, based on geo-ecological zones, not strictly based on a linear scale of payment according to volumes withdrawn.

However, these measures will be fully efficient only if, on the other hand, the transfers to farmers under the Common Agricultural Policy take the protection of water resources more into account.

6. Greece: Sustainable management of water in agriculture: issues and policies

Agriculture in Greece, as is the case in other Mediterranean countries, is still an important sector for food production and employment. An integrated protection plan is necessary to address the sustainable use of water resources used in agriculture taking into account the needs of the environment. Agriculture represents 12 per cent of total G.D.P. and over 20 per cent of the active population is employed in agricultural activities. Agriculture is the largest user of water, in particular for irrigation. The Ministry of Agriculture and the Ministry of Environment, Town Planning and Public Works have the responsibility for planning, financing supervising the implementation of the land reclamation projects for irrigation and drainage.

Agriculture has a need of four-fifths of the country's water supplies. Surface water accounts for approximately six-sevenths of the total quantity of water, and one-third has its origins outside the country. In coastal areas, due to the over-exploitation of ground water aquifers, sea water intrusion has appeared.

The geomorphology, the geological structures, the uneven rainfall distribution in space and time, and diminishing precipitation, have all resulted in the scarcity of water resources during the peak period for irrigation. Because of these reasons, there is a need to construct expensive collective and individual irrigation works.

Twenty-eight per cent of total cultivated area is irrigated, of which 40 per cent is irrigated by collective irrigation works and 60 per cent by individual ones. Many of the existing irrigation systems were designed and constructed many years ago and are still using the same technology. They need to be modernised and rehabilitated for minimising waste, reducing drainage requirements and promoting new technologies, such as ferti-irrigation.

The owners of land covered by collective works are members of the 404 Land Improvement Local Boards. These self-administrated organisations charge their members with service fees that cover the administration, maintenance and operation expenses, while the State finances the construction of the collective works. The 10 Land Improvement General Boards are semi-governmental organisations, established by the government for managing general works. Since 1987, the country has been divided into fourteen water districts. Any legal entity or person must obtain a license for the agricultural use of water. This license is given free of charge. Greece loans are provided by the Agricultural Bank to construct individual works for irrigation, livestock, aquaculture and other agricultural purposes.

The main policy issues relative to water quantity and quality are: i) The complexity of the water property rights based on the law, on customary rules and on administrative licenses. ii) Water deficit, especially during the peak period for irrigation in summer, a period similarly crucial for other uses (tourism, public water supply, domestic sector etc.). iii) Structural impediments, including a large number of small, fragmented farms and of non-farmer owners of cultivated land. iv) The ageing of irrigation works that make them expensive to operate and maintain.

The Greek government has taken measures to address the above issues on water resources management in agriculture and to prevent environmental impacts from agricultural activities: i) Implementation of an "improvement plan" under the EC directives 2328/9 and 950/97 to improve agricultural structures. This "plan" provided terms and conditions for environmental purposes; ii) Environmental Impact Assessment before the construction of infrastructure; iii) Creation of a National Land Registry; iv) *Ex-ante* studies for rehabilitation and modernisation of

the oldest operated collective irrigation works, taking into account users' skills, maintenance cost, crop pattern, skilled labour, and the possibility for locally provided inputs and services; v) Water resources protection plan provided by an annual decision of the local administrative authorities involving permits and penalties; vi) Quality measurement programme of water used for irrigation; vii) Training and educational programmes for farmers.

The expected outcomes are: reduction of wastes in water; minimising energy use; improved drainage; promotion of irrigation in conjunction with better fertilisation, tillage and pest control; protection of water quantity and quality; flexibility for better irrigation services, increased crop diversification and market-oriented agricultural production; and, environmentally and economically sustainable operation of the irrigation systems.

7. Italy: The *Capitanata* irrigation scheme — experiences in water management sustainability

The *Capitanata irrigation scheme* is located in Apulia, southern Italy, and is characterised by scarce water resources and high water losses by crops. It is run by a Consortium (the *Consorzio di Bonifica*) that associates almost all farmers over an area of more than 200 000 hectares. The Consortium is in charge of the water resource survey, distributing water to farms and maintaining the conveyance systems.

Since water is scarce with respect to demand by farmers, the Consortium operates into three directions in order to make the use of water sustainable in semi-arid environments:

- *Extension services*: This covers the services provided through *VIDEOTEL* to farmers for the weekly prediction of water needs by the different crops of the area. It is intended to make *VIDEOTEL* services available on INTERNET. A number of flow meters at the upstream head of the irrigated fields allows to compare the volume used by farmers with the recommended one.
- *Water pricing*: a special tariff (binomial) is applied to those farmers who exceed the irrigation volumes recommended by the technicians of the Consortium.
- *Survey of alternative sources of water*: the possibility of recycling waste waters from cities for use by agriculture is under study.

8. Japan: Sustainable water use in agriculture — existing systems and the possibility of introducing market mechanisms

The Japanese agricultural irrigation system has the following characteristics:

- It depends mainly on water diverted from river flows: 90 per cent of irrigated land depends upon river water.
- It has a long history: most existing irrigation facilities were originally developed some hundred years ago.

- Rice cultivation is the major user of the irrigation facilities, since rice requires a larger amount of water than other crops.
- There are a great many users of irrigation water, reflecting the history of small-scale farming.

These characteristics have led to the establishment of local bodies known as land improvement districts (LIDs or water users' associations). These associations, endorsed by the Land Improvement Act, are voluntarily organised by the farmers themselves, to share the responsibility for water distribution. They are prevalent in regions throughout Japan where rice paddy field agriculture is predominant.

The irrigation sector policy comprises both long-term and short-term perspectives. Regarding long-term policy, major issues for ensuring the sustainability of rice cultivation are:

- securing a set amount of irrigation water; and
- ensuring a constant supply of this volume of water.

Various legal, institutional, and financial measures were established after World War II to address these issues. They include preservation of policy consistency with flood protection, clear definition of water rights, promotion of multi-purpose projects, respect for farmers' initiatives and involvement in planning and implementing projects, defining the roles of Government, local governments, and farmers, and encouraging intersectional transfer of water from agriculture to other uses.

Regarding short-term policy, major issues are:

- ensuring equitable distribution of water in times of drought; and
- minimising government intervention and maintaining financial discipline so that efficiency in distributing water can be achieved and sustained. Several policy measures to address these issues include: ensuring the sustainability and transparency of LID operations through legal and institutional instruments; ensuring 100 per cent recovery of O&M costs from farmers; and encouraging temporary water transfer from agriculture to other uses.

Regarding environmental impact, irrigation for paddy-field rice cultivation has never caused salinity or waterlogging within two thousand years. Moreover, agricultural water channels, with their abundant water flow, have formed part of the traditional Japanese rural landscape that has gradually built up around paddy fields over many hundreds of years.

Future strategies are likely to be:

- to preserve the consistency of policies with agricultural structural reforms;
- to promote water transfer from agriculture to other sectors (or within the agricultural sector when desirable); and
- to pay due attention to the preservation of the environment.

9. Netherlands: Sustainable drinking water supply and dairy production

The “*Baakse Beek*” is a watershed (the water system-unit) located in the eastern part of the Netherlands. It covers about 34 000 hectares, mainly grasslands for dairy production.

Sustainable water management for this watershed can be achieved through redesigning the surface water system, establishing a “water co-operation” with farmers, agreements with the drinking-water production company.

Certain restrictions on agricultural use (e.g. use of nutrients) could be (financially) be compensated by the drinking water production company, for which the availability of groundwater would increase and the costs of purifying groundwater decrease.

10. New Zealand: The impact of policy reforms on water quantity and quality issues

New Zealand agricultural use of water is estimated to total around 350 million cubic metres for livestock farming, and more than one billion cubic metres for irrigation of pasture, agricultural and horticultural crops.

New Zealand has implemented wide ranging economic reforms over the past decade. Markets now play the prime role in the allocation of economic resources, thus ensuring that adjustment occurs on a gradual and continuing basis. Since 1984, government assistance to agriculture has been virtually eliminated.

Although, water used in agriculture is only a small part of the 300 billion cubic metres of water available annually, the combined agricultural, urban and industrial use can place pressure on particular ground water aquifers and surface water resources during summer low flows and/or drought periods. Pastoral agriculture is the main source of pressure on water quality.

In the mid-1980s, the Government reformed its environmental legislation, which culminated in the launching of the Resource Management Act in 1991, under which local authorities have primary responsibility for most environmental issues. Instruments used by these authorities include: regulation and polluter pays principle; user-charges for services such as pest and flood control; and research and development for problems such as erosion and nonpoint source water pollution.

While in the past, Governments had pursued an active policy of promoting and subsidising the development of community irrigation and rural water supply schemes, in 1988, the Government announced its intention to sell its capital share in community irrigation schemes. Ten years later, the asset sales programme is now completed. Very few schemes realised a significant sale price. Efficiency gains are anticipated in the medium to longer term because irrigator ownership will provide greater incentives for efficient operation and maintenance of the schemes.

To mitigate the impact of climate risks and to enhance land productivity, Governments had encouraged use of water resources by providing subsidies for irrigation schemes, and for rural community water supply schemes. Prior to the removal of subsidies in 1988, there were high rates of assistance for irrigation. Now irrigation development must be privately financed, and to proceed requires approval of environmental permits.

User-pays and polluter-pays principles are well established in New Zealand. Farmers are required, for example, to install effluent disposal systems at their own cost and face the prospect of fines if not complying with regional government regulations. Furthermore, for a range of activities, farmers must obtain environmental permits and pay the administrative and on-going monitoring costs associated with permits. To address nonpoint source pollution problems, local authorities are encouraging landowners to take collective responsibility for devising solutions to meet community expectations. To ensure that their production systems are sustainable, the farming sector has taken several initiatives to address environmental issues, including codes of practice, formation of landcare groups and development of on-farm indicators.

Under the Resource Management Act 1991, the resource consent process provides Regional Councils the powers to control water abstraction and diversion, and discharges to water, for stated periods.

More intensive farming systems are placing pressures on available water quantities and water quality. After a decade of fundamental economic, institutional and legislative rethinking and reforms, future changes to policies affecting water use and water quality in New Zealand will largely focus on correcting omissions and anomalies that inevitably emerge from a period of such rapid and wide ranging adjustments.

11. Spain: The institutional management of irrigation water in Spain

As a Mediterranean country whose main climatic features are medium to high temperatures, irregular, uncertain and in general, low precipitation — Spain has, throughout time, frequently experienced severe water shortages during the crop seasons. This situation compelled its first inhabitants to look for solutions to assure crop yields, finding soon that the only way to cope with this unfair condition was to artificially apply water to the crops, i.e. to resort to irrigation. Thus they developed and improved for centuries an advanced system, not only of irrigation networks and application methods and practices, but also of institutions for water management aimed to achieve a sound and equitable share of the always scarce and uncertain water resources.

The result of this experience is the present institutional set-up of irrigation water management, regulated by the Water Act of 1985 (WA/85), now subject to a process of revision in relation to the latest social and technical conditions prevailing in Spain as well as to be in conformity with other international regulations and directives. According to the WA/85 the global water management in Spain is based on two basic principles. First, all waters, either surface or underground, together with the space they affect (known as “water public domain”), are a public good and therefore shall be controlled and administered by the Central Government (the intra-communities basins) or its equivalent in the Autonomous Regions (the inter-communities basins), according to the Nation’s or Region’s general interests. The Ministry of the Environment and the Regional Governments are the only ones entitled to grant concessions for water use and for specific purposes. Second, the global water administration is based on the principle of river watershed hydraulic unity.

The administration and management of water resources within each river basin, as well as the entitlement to grant concessions to use water in the water public domain, is entrusted to the River Basin Authorities. These Agencies are mixed institutions governed by Boards composed of officials belonging to the Central Administration and water rights users, in proportion to the (economic) interests concerned. For instance, the average composition of the Governing Boards of all the

Spanish River Basin Authorities is roughly 51 per cent administration officials, 35 per cent users other than irrigators (urban supplies, industries, power plants, etc.) and 14 per cent irrigators.

In turn, according to the WA/85, all farmers or users, withdrawing water from a single source or benefiting of a single concession must form a Users Association (UA) or an Irrigators Community (IC). These are independent institutions that, although attached to the Basin Authorities, are regulated by their own Ordinances and governed by different and specific bodies. Their members are democratically elected among the users, and are responsible for the *legislative, executive and judicial* functions, respectively performed by the General Assembly, the Governing Board and the Irrigation Jury or Water Court. The latter is aimed to achieve: the best use and most equitable share of water available to avoid water wasting or misuse and so reducing environmental hazards; to maintain infrastructures in good state of use and improve the irrigation system and application methods in order to raise efficiencies; and to settle disputes between users or users and Community's personnel, etc.

Several small ICs within irrigated areas may group together in a Central Board or a General Community to improve performance, strengthen their position for the defence of their common interests, and benefit from the assistance of technical services that could otherwise be unaffordable. This is the case of the General Community of Urgel Canals Irrigators (GCUCI), which groups 21 Ordinary Communities or Collectivities, subdivided into 125 districts or irrigation sectors, which permits personal attention given to individual farmers and assures the best and quickest solution to their problems through the governing bodies, either of the Collectivity or of the General Community.

The governing bodies of the GCUCI, and particularly the Governing Board are assisted by technical, administrative and water distribution services that support the Board in all management decisions such as the filling and discharge regimes of the Oliana reservoir and the volumes diverted through the main Urgel Canals, etc. The organisational set-up of this General Community has proved to be highly effective not only from a human point of view but also as the best tool to achieve important economies of irrigation water and a more protective behaviour to the environment. This experience deserves consideration as it could be applied in other countries.

12. Switzerland: Swiss agri-environmental policy and water quality

The key issue associated with water quality in Switzerland is the nitrogen content of groundwater. The maximum tolerated level of 40 mg NO₃/l is exceeded in some agricultural areas. Around 75 per cent of nitrate leaching into groundwater originates from soils used for agricultural purposes. For running water and groundwater the set target is 25 mg/l NO₃-N for nitrate and 0.0001 mg/l of active ingredient for pesticides.

It is expected that, by year 2002, on the basis of current trends and measures that can be implemented by then, the pollution of air and water bodies by agriculture can be reduced from 96 000 to 74 000 tonnes N per year nation-wide, representing a cut of around 23 per cent compared to 1994. These predictions are based on the Water Protection Act, the Ordinance on Pollutants of the Environmental Protection Act and the agricultural policy reform process.

The water protection act obliges livestock holders to be equipped with farm manure storage facilities with a capacity of at least 3 months. It lays down a maximum stocking rate of 3 Livestock Units-Manure (or 315 kg total N and 45 kg P) per hectare of agricultural area for each individual farm

in the valley areas. The Cantons may be compelled to set lower values in certain cases, depending on the site concerned.

The ordinance on pollutants stipulates, *inter alia*, that waste product and mineral fertilisers may be used only in cases where the farm's own manure supply is insufficient or ill-adapted to the nutrient requirements of the plants.

The agricultural policy reform process allows ecological services to be compensated by means of direct payments. This is implemented through three main ecological programmes: Integrated Production (IP), Organic Farming (Org.) and Ecological Compensation. Only those farms that are able, *inter alia*, to demonstrate a levelled out nutrient balance are entitled to participate in the IP and Org. programmes. By 1996, 60 per cent of Switzerland's agricultural area was already farmed according to integrated production methods and 5 per cent of the area met the requirements of organic farming.

According to model calculations, the greatest impact on the nitrogen balance is expected to result from the agricultural policy reform process. This process will allow a 23 per cent reduction of the N-loss potential in the years to come and will also produce considerable changes in the agricultural structure. Depending on the period considered, it will lead to savings in the national economy of between 340 and 680 million Swiss Francs (between 235 and 469 million US dollars). The additional federal budgetary expenditure on direct payments would amount to SF 700 million (US\$483 million) between 1995 and 2002, with a simultaneous reduction for the burden on consumers of SF 1 400 million (US\$996 million). Annual value added for the agricultural sector should decrease by SF 200 million (US\$138 million) a year over this period. The legal bases for the second step of the agricultural policy reform process are currently being discussed at Parliament level and are expected to take effect at the beginning of 1999 at the earliest.

13. Turkey: Management of water resources for agriculture

Turkey has a land area of 78 million hectares, of which 28 million hectares are cultivated. Annual rainfall averages 500 cubic kilometres. Fresh water available for consumption is estimated at 110 cubic kilometres, excluding outflows reserved for neighbouring countries and water used to prevent saltwater intrusion, to preserve aquatic life, and to dilute pollutants. Precipitation varies annually and regionally within a range of 250 to 3 000 millimetres, which in the drier areas of the country, means that there is a demand for irrigation water in order to produce agricultural commodities. Two-thirds of the 34 cubic kilometres of water consumed annually in Turkey is used for agriculture.

The Government has invested heavily in irrigation infrastructure since the 1950s. Over the last decade, public investment in irrigation has averaged over US\$ 500 million annually, converting an additional 80 to 100 thousand hectares of land to irrigation each year. Out of the 8.5 million hectares where there is a potential for irrigation, 4.5 million hectares are currently covered by irrigation schemes. Schemes developed by farmers themselves account for approximately 1 million hectares, while those built by public agencies account for the remaining 3.5 million hectares.

Two General Directorates are responsible for developing irrigation in Turkey: the State Hydraulic Works (DSI), which is a General Directorate under the Ministry of Energy and Natural Resources; and the General Directorate of Rural Services (GDRS), which reports to the Prime

Ministry. Large-scale surface-fed irrigation systems are developed by DSI and small-scale systems by GDRS. Groundwater-fed irrigation schemes are developed by both agencies (wells by DSI and distribution systems by GDRS).

Groundwater systems are operated and maintained by irrigation co-operatives. Until recently, all large-scale schemes, and most small-scale schemes which have been developed by DSI were managed by DSI. In 1993, a programme was created to transfer responsibility for the operation and maintenance of these irrigation schemes to water user organisations. Until now, more than 1.1 million hectares have been transferred to user organisations. This change has increased collection rates of irrigation charges, increased the area actually irrigated, improved allocation of water among users, and, most importantly, increased efficiency of agricultural water use.

14. United States: U.S. water management for agriculture — a case study of the American west

The availability of water has been central to both the U.S. agricultural economy and to economic development in the western States. For many years, production agriculture benefited from Federally subsidised water and western economic expansion thrived on the construction of reservoirs, aqueducts, and distribution systems to meet increasing water needs. Today, a new economic and political environment calls for non-structural water development through co-operative management, conservation, voluntary water marketing, and increased attention to environmental protection. However, the policies that guide water development and management are changing slowly to accommodate this new environment. The public sector in water management is changing, and institutional and policy reforms are taking place, that promote economic efficiency and meet multiple and competing needs.

15. CEC: The European Commission proposal for an EU-Water Framework Directive

A proposal for a Water Framework Directive was put forward by the European Commission in February 1997 and is currently being considered by the European Council and the European Parliament. The proposal aims at providing a context in which existing Community requirements on water pollution and water quantity can be integrated with each other and with local policy objectives in an overall water management system. Existing legislation tackles isolated problems: a global quality goal is needed to which all these measures contribute, and against which their effectiveness can be judged.

European Union Member States are required to identify river basins, the geographic unit on which to manage their waters, because by managing the river system as a whole actions can be taken at the most appropriate point in the system. EU Member States must designate authorities responsible for implementing all the requirements of the Directive. The objective of good ecological status must be achieved for all waters by 2010. Derogation from this objective is allowed only in few cases, under certain circumstances. EU Member States must design a programme of measures for each River Basin to achieve this objective.

On 15 December 1997 the European Commission issued for consultation a draft modification for the Directive elaborating Annex V of the proposal, including the concept of good status. The proposal draws substantially on work done in an Experts Working Group of the European Council under the

Luxembourg Presidency. Adoption of the proposal by the Commission is foreseen for mid-January 1998.

The Directive sets out a combined approach, which consists of controlling emissions to water through Best Available Techniques (BAT) as a first step, followed by any additional measures needed to achieve the quality objective. For large installations BAT controls are provided by Directive 96/61 on Integrated Pollution Prevention and Control. For small installations such controls are not in place. Therefore the Commission proposed a revision of the Water Framework Directive to integrate the required controls. The revision comprises: selection of priority substances for Community action on the basis of risk; uniform BAT based production and process controls (emission limit values or their equivalent) set at European level; complementary measures on products. The revision was adopted by the European Commission on 26 November 1997.

The need to conserve adequate supplies of a resource for which demand is continuously increasing is also one of the driving forces behind what is one of the proposed Framework Directive most important innovations — the introduction of “*full cost recovery*” pricing. By 2010 Member States will be required to ensure that the price charged to households, farmers and industry for water services — such as the abstraction and distribution of fresh water and the collection and treatment of waste water — reflects the true costs. The full cost will also have to include (on the basis of a Commission proposal that will come later) the costs of water use in terms of the damage to the environment it can cause and the depletion of water resources for future generations.

The proposal further requires that cross-subsidisation between the household, industrial and agricultural sectors does not take place. Governments would, however, be able to make an exception to ensure that households are charged at affordable prices for a basic level of water use. But for agriculture in many countries it would mean a considerable change.

16. UN/ECE (United Nations Economic commission for Europe): Water and agriculture — policy requirements in Europe

The activities of the UN/ECE aimed at the harmonisation and convergence of policies and strategies to prevent, control and reduce the pollution of inland waters, including transboundary watercourses, lakes and groundwaters in Europe. Intensive negotiations and co-operative actions have led to reach agreements on a number of non-binding and binding instruments, including the ECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (also referred to as the Water Convention). These instruments also relate to the prevention and control of water pollution from agriculture.

17. CIHEAM (International Centre for Advanced Mediterranean Agronomic Studies): Priority actions for water resource management in the Mediterranean countries

Consumption of fresh water for domestic, agricultural, energy and industrial purposes is expected to greatly increase by the end of the century for a number of reasons: population growth; the extension of irrigation to increase agricultural output; the foreseeable development of water distribution systems; and the expansion of water-consuming industrial activities.

Although, water resources are globally well in excess of foreseeable demand, they are unevenly distributed. Some regions are already experiencing severe water shortages which may worsen in the

future. This can have serious repercussions on the economy and the environment. In many cases, the situation is further aggravated by the poor quality of water which makes it unsuitable for various purposes.

The solution to the problem of water resources lies in rational management which should be concerned both with supply and demand, and built on solid scientific and technical foundations, and rely on an interdisciplinary approach to the ecological, economic and social problems. Such management should aim at promoting the use of water resources in such a way as to ensure the satisfaction of society's needs while preserving them for the future.

Economic and social changes necessitate the development of water resources based on sound environmental principles. A sound scientific understanding should be the foundation upon which rational decisions regarding water resource management should be taken.

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